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by

Roger James Dean

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LAND APPLICATION OF EFFLUENTS
IN THE ROCKY MOUNTAIN-PRAIRIE REGION

by

Roger James Dean

B.S., Augustana College, 1960

A thesis submitted to the Faculty of the Graduate
School of the University of Colorado in partial
fulfillment of the requirements for the degree of
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Department of Civil and Environmental Engineering
1974

This Thesis for the Master of Science Degree by

Roger James Dean

has been approved for the

Department of

Civil and Environmental Engineering

by

J Ernest Flack

J. Ernest Flack

Edwin R Bennett

Edwin R. Bennett

Date April 18, 1974

ABSTRACT

Dean, Roger James (M.S., Civil and Environmental
Engineering)

Land Application of Effluents in the Rocky Mountain-
Prairie Region

Thesis directed by Professor J. Ernest Flack

The Federal Water Pollution Control Act Amendments of 1972 and more stringent State water quality standards for surface waters have revived interest in the land application of effluents as a wastewater treatment method. Articles discussing various aspects of the concept appear in the literature with increasing frequency.

Legal, environmental, social, economic and engineering factors must be included in the evaluation of existing systems or the consideration of new systems. Each factor also affects the cost effectiveness of land application as a wastewater treatment alternative. These factors are site specific in terms of politics, law, water rights, climate, topography, soil type, hydrology, geology, and agricultural practices. Care must, therefore, be exercised when comparing land treatment sites or estimating the cost and efficiency of a proposed site based on the performance of another site. This thesis includes a compilation of the more significant factors for consideration, a brief discussion of the importance and interrelationship of each factor, and their impact on cost analysis.

A survey of the use of land application of wastewater effluents was conducted encompassing the Rocky Mountain-Prairie Region of the Environmental Protection Agency, Region VIII, which includes the States of Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming. Of prime interest were those sites utilizing spray irrigation, overland flow or ridge and furrow irrigation which had pre-planned or intentional direct uses of effluents. Not included were sites where dilution or ultimate destination of the effluent was unknown. The main survey topics included: flow and storage, pretreatment, significant effluent water characteristics, soil, geological, and topographical characteristics of the site, irrigation methods used, crop and land use, environmental monitoring of the site, and capital and operating and maintenance costs. Six industrial and thirty-seven municipal sites were surveyed. The results of the survey indicated a general lack of State control over engineering, environmental, or monitoring considerations necessary for proper operation and management of land treatment sites and a corresponding lack of awareness or concern for those factors by most site operators.

This abstract is approved as to form and content.

Signed J Ernest Flack
Faculty member in charge of thesis

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CHAPTER I

INTRODUCTION

Land Treatment Systems

The land application of effluents is a wastewater treatment method which takes advantage of the physical, chemical and biological renovative characteristics of the soil. Modern land treatment systems are grouped as crop irrigation, overland flow or spray-runoff, and infiltration-percolation.

The crop irrigation method utilizes standard spray irrigation equipment such as center pivot, solid set or portable irrigation rigs to apply wastewater to selected crops. Surface application methods include ridge and furrow, overland flow, and border irrigation.

Spray-runoff or overland flow is an adaptation of spray irrigation using natural sloping terrain terraced into separate small areas. Wastewater is treated by flowing to collection ditches through vegetation growing on an impermeable soil. The collection ditches discharge the treated wastewater to a receiving stream. Biological treatment occurs as the wastewater trickles through the vegetative litter and contacts the biota and the soil.

Infiltration-percolation methods utilize diked areas over permeable soil formations. The intent is to simultaneously achieve wastewater treatment and groundwater recharge. Alternate cycles of flooding, infiltration, and drying are required to maintain the soil infiltration capacity.

The emphasis in this thesis will be on three subjects related to land treatment:

(1) Spray irrigation systems--it is the predominant method used for land treatment of wastewater in the Rocky Mountain-Prairie Region.

(2) Legal, environmental, social, economic and engineering factors--they all must be included in the evaluation of existing systems or the consideration of new systems.

(3) Present practices in Region VIII--the results of a survey of land application systems and systems performance within Region VIII of the Environmental Protection Agency (EPA) will be presented. EPA Region VIII, the Rocky Mountain-Prairie Region, includes the states of Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming.

Factors affecting the efficacy of land treatment are site specific in terms of politics, law, water rights, climate, topography, soil type, hydrology, geology, cost effectiveness, and agricultural practices.

The results will be generalized in terms of identification of the significant factors, their importance to cost effective analysis and design of land treatment systems, and actual Regional experiences and practices of land treatment.

Historical Perspective

The application of sewage effluents to the land has been historically termed "sewage farming". References to sewage farming date as far back as 1559 for Bunzlau, Germany. In the United States references date as far back as 1872 for Augusta, Maine. The 1972 Municipal Wastewater Facilities Inventory, published by the EPA, identified 571 municipal surface application systems in the United States.[1] The total number of industrial systems is not known, but using historic municipal to industrial facilities ratios would indicate that at least an equal number of industrial systems probably exist.

There is nothing new about the basic concept of spreading treated or untreated sewage or liquid wastes on the land as a means of disposal. What is new is the objective of making this method of disposal a scientifically evaluated, professionally designed, and properly operated and maintained treatment process which can meet the criterion of a "best practicable technology". The more specific definition of "land application of effluents" usually refers to the application of municipal effluents onto land areas after treatment approaching secondary treatment quality criteria. Pretreatment requirements for industrial wastes are determined by the individual process involved.

There also is a new awareness that ground waters need to be protected from pollution just as diligently as surface waters because groundwater may remain polluted for years, decades, or centuries. The average residence time of a pollutant in groundwater can be as long as 200 years.[2]

Land application of effluents is currently considered to be advanced waste treatment for removal of suspended solids, biodegradable organics, nutrients and pathogens. Land application is thus viewed as an alternative to other physical-chemical-biological methods of tertiary treatment.

Acute or chronic quantities of toxic trace elements, salts, heavy metals and refactory organics are severe pollutants on land just as they are in streams. Toxic wastes may poison the soil biological systems responsible for the renovation processes and cause long term or irreversible damage to soil systems and groundwater. They may be concentrated within plants used for agriculture production and cause toxicity in higher animals, including man, when used as food or feed. Soil and groundwater pollution, therefore, need to be at least as strictly controlled and monitored as pollution of rivers and lakes.

The effectiveness of land application must be judged by what it accomplishes and not used merely as a means of avoiding the direct discharge of treated effluents into receiving waters. Water is a limited resource, especially in the Western United States. Denying downstream users the use of part of the effluent because of the water lost to evapotranspiration in land treatment may not be in the best interest of the regional or national economy.

Past U.S. Experiences

The American Public Works Association Research Foundation, in 1972, conducted a field survey of 100 facilities utilizing the land application of municipal or industrial wastewaters. Facilities utilizing municipal wastewaters (75) were predominantly in the western and southwestern portions of the nation. Industrial facilities (25), primarily fruit and vegetable processing plants, were predominantly in the northeastern section. Selection of the sites to be surveyed was weighted towards the larger long-established facilities to obtain as much information as possible on operating experience. Adequate field survey data was obtained from 69 municipal and 19 industrial facilities to form the data base used in the analysis. The following are presented to give a composite picture of the observations made:[3]

1. Communities generally use their land application system on a continuous basis. Food processing plants, the predominant industrial users of the system, generally use discharge-to-land systems for three to eight months per year.
2. Ground cover utilized for municipal systems is divided between grass and crops. Industries generally use grass cover.
3. Land application systems are usually used on a daily basis, seven days per week.
4. Application rates for crop irrigation are very low in terms of inches of water per week. Two inches or less was common.
5. Many types of soils were utilized although sand, loam and silt were the most common classifications given. Two systems on deep sand were applying up to eight inches per day once a week, contrasted with another system on clay applying a daily rate of 0.1 inch.
6. Most operating agencies, municipal and industrial, are planning to either expand or continue their land application installations. The few examples of systems which had been abandoned gave as the reason either the desire to make a higher use of the land, or because of reported overloading and incompetent operation of the land application facilities.

7. Industries surveyed generally treat their total waste flow by land application. Municipalities apply from less than 25 percent, to all the wastewaters discharged.

8. Secondary treatment and lagoon storage are generally, but not always, provided by municipalities prior to land application. Industries frequently treated their process wastes by screening only.

9. Spray irrigation is the most frequently used (57 facilities) method of application, although most municipalities use more than one method. Ridge-and-furrow irrigation is used at 23 facilities and flooding irrigation by 34 systems. Industry generally used spray irrigation.

10. Land use zoning for land application sites is predominantly classified as agriculture, with some residential zoning in contiguous areas.

11. Wastewater generally is transported to the application site by pressure lines, although a number of municipalities are able to utilize ditches or gravity flow pipelines.

12. Many municipal land application facilities have been in use for several years--more than half for over 15 years. Industrial systems generally have been in use for a shorter period of time.

13. Renovated wastewater is seldom collected by underdrains; rather, evaporation, plant transpiration, and groundwater recharge take up the flow.

14. In general, no appreciable efforts are made to preclude public access. Residences are frequently located adjacent to land application sites.

No special effort is made to seclude land application areas or to exclude recreationists from the sites.

15. Measurement and monitoring of groundwater quality, soil uptake of contaminants, crop uptake of wastewater components, and surface water impacts are not carried out at all or are not done with any consistency.

The study indicated that existing land application systems are serving predominantly small communities and industrial sites. Seventy-three percent of the municipal and all the industrial sites have land application capacities of under 5 MGD. Little concern or protective measures were shown for deterioration of the environment in the application areas or for the impact on contiguous lands and their occupants. Security provisions against trespassers or against the dispersal of aerosols to surrounding areas through use of fencing or buffer zones were not common practice. Monitoring of groundwater, surface water sources, soils, animals or insects were not common and were often dependent solely on the requirements of public health authorities. The survey of state health and water pollution control agencies indicated that most state agencies have no set policies on land application of effluents or the attendant environmental impacts. State agencies do not impose specific conditions on installations, seldom inspect existing systems, and seldom require monitoring procedures and the filing of official reports on operation.[4]

California appears to have the most land application sites (132). The California land application systems process an annual volume of about 46 billion gallons. This is approximately the amount of water used for all purposes in California during one day,[5] and gives an average site size of 0.95 MGD. Only four sites in the state exceed 3 MGD.[6] The breakdown as to site use, with several sites having more than one use,[7] is as follows:

Use of Site	Number
Non-food crops (includes fodder, fiber, and seed crops)	88
Landscape irrigation (includes parks, golf courses, and freeway landscape)	36
Food crops	11
Groundwater recharge	7
Ornamental lakes	5
Industrial use	4
Recreational lakes	3
Wildlife habitat	1

California regulations for use of wastewaters were adopted in 1918 and revised in 1933, 1968 and 1973.[8]

The use of wastewater in California for landscape irrigation has been dictated in almost every case by the economic advantage favoring its use; the only alternative was irrigation with wastewater since the price of fresh water would be prohibitively expensive.[9]

California, while quite liberal on most effluent parameters, is restrictive in the health areas due to unknown aspects such as virus survivability and transport. The State requires a coliform MPN of 23/100 ml for irrigation of public areas such as golf courses and 2.2/100 ml for recreational lakes and food crop irrigation.[10]

The State of New York has 24 municipal sites designed to process 9.5 MGD (0.40 MGD average) and 12 industrial sites designed to dispose of 5.2 MGD (0.43 MGD average). Guidelines for selection and design of land treatment sites are being developed.[11]

Pennsylvania has 75 spray irrigation sites in operation. Most are small industrial applications. State regulatory experience with these systems has been generally poor due to improper system design and management errors. To prevent continued pollution of groundwater, Pennsylvania now requires the installations to have discharge permits and has published regulations and guidelines for site selection and system design.[12]

From the historical aspect, it appears that past experience with land application of effluents has been with small systems; unmonitored; unregulated; and beset with numerous design and management problems.

CHAPTER II

LEGAL CONSIDERATIONS

Federal Water Pollution Control Act Amendments of 1972

The Federal Water Pollution Control Act Amendments of 1972 were enacted on October 18, 1972. The Act outlines a sweeping Federal-State-local government campaign aimed toward preventing, reducing and eliminating pollution. Title II of the Act authorizes a multi-billion dollar program to assist communities by providing 75 percent Federally funded grants for constructing sewage treatment facilities. Land treatment systems are included. The major stipulation is that any assisted sewage project must be chosen on the basis of the most cost effective method over the life of the works. Sections 201 and 212 of the Act are directly concerned with land treatment.

Section 201, regarding grants for construction of treatment works:[13]

> (d) The Administrator shall encourage waste treatment management which results in the construction of revenue producing facilities providing for--
>
> (1) The recycling of potential sewage pollutants through the production of agriculture, silviculture, or aquaculture products, or any combination thereof;
>
> (2) The confined and contained disposal of pollutants not recycled;

(3) The reclamation of wastewater; and

(4) The ultimate disposal of sludge in a manner that will not result in environmental hazards.

(f) The Administrator shall encourage waste treatment management which combines 'open-space' and recreational considerations with such management.

(g)(2) The Administrator shall not make grants from funds authorized for any fiscal year beginning after June 30, 1974, to any state municipality, or intermunicipal or interstate agency for the erection, building, acquisition, alteration, remodeling, improvement, or extension of treatment works unless the grant applicant has satisfactorily demonstrated to the Administrator that--

(A) Alternative waste management techniques have been studied and evaluated and the works proposed for grant assistance will provide for the application of the best practicable waste treatment technology over the life of the works consistent with the purposes of this title; and

(B) As appropriate, the works proposed for grant assistance will take into account and allow to the extent practicable the application of technology at a later date which will provide for the reclaiming or recycling of water or otherwise eliminate the discharge of pollutants.

In expanding on this section, Sullivan[14] quoted from House Report No. 92-911 (on the 1972 Amendments) as follows:

The Committee believes that applicants must in the future be required to examine a much broader range of alternatives for the treatment of pollutants than they have heretofore typically done. It expects the Administrator to provide leadership and to stimulate research to assure the development and application of new treatment techniques. In arriving at the best practicable waste treatment technology consideration must be given to its full environmental impact on water, land, and air and not simply to the impact on water quality. There may be no net gain to the Nation if we adopt a technology to improve water quality without recognizing its possible adverse effect on our land and air resources.

The term 'best practicable waste treatment technology' covers a range of possible technologies. There are essentially three categories of alternatives available in selection of wastewater treatment and disposal techniques. These are (1) treatment and discharge to receiving waters, (2) treatment and reuse, and (3) spray irrigation or other land disposal methods. No single treatment or disposal technique can be considered to be a panacea for all situations and selection of the best alternative can only be made after careful study.

Particular attention should be given to treatment and disposal techniques which recycle organic matter and nutrients within the ecological cycle.

In defining 'best practicable waste treatment technology' for a given case, consideration must be given to new or improved treatment techniques which have been developed and are now considered to be ready for full-scale application. These include land disposal, use of pure oxygen in the activated sludge process, physical-chemical treatment

> as a replacement for biological treatment, phosphorous and nitrogen removal, in collection line treatment, and activated carbon adsorption for removal of organics. Planners must also give consideration, however, to future use of new techniques that are now being developed and plan facilities to adapt to new techniques.

Section 212 of the Act authorizes federal cost sharing for site acquisition of the land that will be an integral part of the treatment process.[15]

Regarding groundwater pollution, the Act states in Section 102(a):[16]

> Section 102(a). The Administrator shall, after careful investigation, and in cooperation with other Federal agencies, State water pollution control agencies, interstate agencies, and the municipalities and industries involved, prepare or develop comprehensive programs for preventing, reducing, or eliminating the pollution of the navigable waters and ground waters and improving the sanitary conditions of surface and underground waters. In the development of such comprehensive programs due regard shall be given to the improvements which are necessary to conserve such waters for the protection and propagation of fish and aquatic life and wildlife, recreational purposes, and the withdrawal of such waters for public water supply, agricultural, industrial, and other purposes.
>
> For the purposes of this section, the Administrator is authorized to make joint investigations with any such agencies of the condition of any waters in any State or States and of the discharges of any sewage, industrial wastes, or substance which may advereely affect such waters.

Section 104(a)(5), regarding national program requirements:[17]

> (5) In cooperation with the States, and their political subdivisions, and other Federal agencies, [the Administrator shall] establish, equip, and maintain a water quality surveillance system for the purpose of monitoring the quality of the navigable waters and groundwaters ...

Section 106, regarding grants for pollution control programs:[18]

> (e) Beginning in fiscal year 1974 the Administrator shall not make any grant under this section to any State which has not provided or is not carrying out as a part of its program--
>
> (1) The establishment and operation of appropriate devices, methods, systems, and procedures necessary to monitor, and to compile and analyze data on (including classification according to eutrophic condition), the quality of navigable waters and to the extent practicable, groundwaters including biological monitoring; and provision for annually updating such data and including it in the report required under Section 305 of this Act;

Section 208, regarding areawide waste treatment management, states that such plans shall include:[19]

> (2)(k) A process to control the disposal of pollutants on land or in subsurface excavations within such area to protect ground and surface water quality.

Section 304, regarding information and guidelines, describes the development of water quality criteria reflecting the latest scientific knowledge on the health effects to all forms of life due to the presence of pollutants in any body of water, including groundwater.[20]

It should also be noted that Section 502, General Definitions:[21]

> (7) The term 'navigable waters' means the waters of the United States, including the territorial seas.

Additional clarification of the 'navigable waters' definition, as it relates to the discharge permit system, states that navigable waters include: navigable waters; tributaries of navigable waters; interstate waters; and intrastate lakes, rivers, and streams involved in interstate recreation or commerce.[22]

EPA Rules and Regulations

This section includes a brief description of some of the significant proposed or promulgated EPA rules and regulations applicable to land treatment. The intent is to indicate the direction, the complexity and the comprehensive nature of this activity.

Environmental impact statements must be prepared for Federal grant supported construction where significant environmental effects are anticipated or when the environmental impact of an action is likely to be highly controversial.[23]

The requirement for discharge permits for land treatment sites is presently at the discretion of the individual states if the site has no direct discharge to surface waters. The National Pollutant Discharge Elimination System[24] (NPDES) for issuing discharge permits is presently not directly applicable unless the land treatment site has a discrete return flow to surface waters. Any land treatment site with a return flow discharging to surface waters is considered to be a "treatment works" with a direct surface discharge. The definition of treatment works in the regulation states:[25]

> The term 'treatment works' means any facility, method or system for the storage, treatment, recycling, or reclamation of municipal sewage or industrial wastes of a liquid nature, including waste in combined storm water and sanitary sewer systems.

States can impose more stringent treatment standards or require permits for any form of discharge.

Cost effective analysis of municipal land treatment alternatives will have to be prepared for those construction grants receiving federal funds after June 30, 1974. The extent of the analysis is defined in the EPA cost effective guidelines.[26]

Municipal land treatment sites may implement the pretreatment regulations for control of industrial discharges to publicly owned treatment works where the discharge contains toxic wastes that are not conducive to land treatment.[27] The actual pretreatment requirements or allowable discharges for various industries have been published in various issues of the Federal Register starting on October 5, 1973.

The minimum requirement of secondary treatment must be met by July 1, 1977 by all publicly owned treatment works which discharge to navigable waters.[28] This requirement will be an impetus to planners to consider land treatment as an add-on method for achieving secondary treatment requirements for treatment systems such as lagoons which do not consistently meet the BOD, suspended solids, or coliform requirements.

The application of "best practicable waste treatment technology" (BPWTT) must be demonstrated for federal construction grants after June 30, 1974. All existing publicly owned treatment works must comply with the requirements by July 1, 1983. The preliminary proposed requirements which pertain specifically to land treatment systems require that sites with point source discharges, such as underdrains, would be required to comply with the treatment and surface discharge criteria. Land application sites, with discharges to groundwater, would be required to comply with EPA drinking water quality criteria for chemical and pesticide content of the groundwater below the site (Reference Table I for proposed chemical constituent requirements). Monitoring procedures would be required for all the specified parameters. The preliminary proposed requirements for discharge to groundwater by land application sites are:[29]

> 137.103 Definition of Best Practicable Waste Treatment Technology for Land Application Techniques and Land Utilization Practices
>
> The following defines the criteria required for the application of the best practicable waste treatment technology for land application techniques (e.g., spray irrigation, infiltration, overland flow techniques and evaporation ponds) and land utilization practices including irrigation of biologically digested sludge, chemically stabilized sludge, composting and land spreading of sludge and leaching fields for publicly owned treatment works.
>
> (a) The information in Paragraph 137.102 defines the allowable concentration of pollutants in the effluent from a land disposal system discharged into navigable waters.
>
> (b) For the purposes of establishing eligibility for grant funding, the discharge of pollutants onto the land should not degrade the air, land, or water (either navigable waters or groundwaters) and should not interfere with the attainment or maintenance of public health; state and local land use policies; water quality in navigable and groundwaters which shall assure protection of public water supplies, agriculture and industrial users;

> propagation of a balanced population of aquatic and land flora and fauna; and the recreational activities in the area. The land application system shall be designed such that the permanent groundwaters (groundwater which is not removed from the ground by an underdrain system or other mechanical means) which are in the zone of saturation (where the water is not held in the ground by capillary tension) that result from the application of wastewater shall not exceed the chemical quality or pesticides levels in the EPA Manual for Evaluating Public Drinking Water Supplies...
>
> (d) If the presently existing concentration of any parameter is higher in the groundwater than the levels allowed in subparagraph 137.103 (b)(1), then the use of a land disposal technique should not result in an increase in the concentration of that parameter.

The method for imposing the proposed EPA requirements on existing land application facilities or incorporating the requirements into federal and state permit systems is not indicated. The present EPA position on the protection of groundwaters, however, is quite obvious.

State Laws and Regulations

A survey conducted in 1972 by the American Public Works Administration (APWA) among State health and water pollution control agencies indicated that most State agencies presently have no set policies, conditions, inspections, or monitoring requirements with regard to land treatment. States that have some form of regulation include Florida, Pennsylvania, New York, Arizona, California, Texas, and the Great Lakes Upper Mississippi River Board.[30]

The following information for the six states of Region VIII was compiled from the APWA survey documents obtained from the respective states, and other reference sources.

Colorado.

Colorado's Criteria Used in the Review of Waste Water Treatment Facilities[31] states in paragraph 8.4, Land Disposal of Effluent: "Since roughly 50 percent of wastewaters discharged to the land surface will infiltrate and recharge groundwater, all irrigation installations are considered discharges to the waters of the state". No other references to land treatment facilities or standards are included. The first draft of the proposed Water Quality Standards for Colorado,[32] November 1973, does not address groundwater quality standards. In responding to the APWA survey, the Colorado Department of Health indicated that chlorination of effluents was required, whereas the Water Resources Control Board [sic, Colorado Water Conservation Board] indicated that there were no specific regulations or guidelines.[33]

Colorado has promulgated regulations for privately-owned aerobic sewage treatment works.[34] These regulations could be construed as applying to privately-owned land application systems, however no indication of such an interpretation was found during the survey of Colorado sites. A separate survey conducted by Temple University also elicited a Colorado State Health Department response that regulations concerning spray irrigation were not currently in force.[35]

Montana.

Direct reference to land treatment or groundwater quality regulations or criteria was not found in a review of Montana regulations. Groundwater is classified as property of the state.[36] The proposed Montana Water Quality Standards state that pollution resulting from non-point sources, including irrigation practices, are to be eliminated or minimized as ordered by the department.[37] In responding to the APWA survey, the Montana Department of Health indicated there were no specific rules or statutes dealing with land treatment, and that each case was examined individually. Secondary treatment and chlorination of effluents are usually required and winter effluent flow must be stored.[38] This concerns with the results of the Temple University Survey.[39]

North Dakota.

Direct reference to land treatment or groundwater quality criteria or regulations was not found in a review of the North Dakota Water Quality Standards.[40] Groundwaters are waters of the state. The APWA survey[41] and the Temple University survey[42] found no specific regulations regarding land treatment.

South Dakota.

Direct reference to land treatment or groundwater quality criteria or regulations was not found in a review of the South Dakota Water Quality Standards.[43] Groundwaters are waters of the state. The APWA survey concluded "no regulation--each site considered individually"[44] and the Temple University survey found no regulations.[45]

Utah.

Groundwaters are waters of the state in Utah and the Division of Health appears to have a negative attitude towards spray irrigation. This is shown in the only reference that could be found regarding land treatment or groundwater quality criteria or regulations:[46]

> Wastewater treatment works effluent which meets Class 'D' Standards or better may be utilized for the following purposes...(3) Ridge and furrow irrigation or flood irrigation of lawn areas from which the public is excluded except on guided tours, but not public parks, golf courses, or similar

> areas of public access. (Spray irrigation is not recommended under any circumstances.) (4) Ridge and furrow irrigation of forage type crops, but not dairy pastures.

Utah Class "D" waters require: chemical and radiological standards as prescribed for drinking water by "Public Health Service Drinking Water Standards, 1962"; monthly mean coliform density of less than 5000 per 100 ml; and monthly mean BOD of 25 mg/l or less.[47] The APWA survey found no regulations on land treatment.[48]

Wyoming.

Direct reference to land treatment or groundwater quality or regulations was not found in a review of the Wyoming Water Quality Standards.[49] Groundwaters are waters of the state. The APWA survey[50] and Temple University survey[51] found no specific regulations on land treatment. A 1959 statute (Wyoming Statute Section 41-121, 41-126) states that pollution of underground water means any impairment of the natural quality of such water, however caused, including impairment by salines, minerals, industrial wastes, domestic wastes, or sewage. The State Engineer is authorized to require the abatement of any condition responsible for admitting polluting materials into an underground water supply.[52]

County and Local Laws and Regulations

There are several local factors that will be encountered in site selection for a new land application site or future use and expansion of a present site. Those which should be considered include:

1. Conformity to state or regional land use plans.
2. Conformity to county or metropolitan land use plans or comprehensive plans.
3. Present and future land use zoning versus future residential growth versus wastewater transmission costs. Increasing monitoring requirements as adjacent residential development occurs.
4. Approval must be obtained from several levels of local government and several Boards of Health if the site is outside the jurisdiction of the municipality or county it serves.
5. Power of eminent domain--in most states a county or municipality has no authority to condemn property owned by another municipality, county, the state or federal government.
6. Payments in lieu of taxes may have to be made if the amount of land being removed from the tax rolls is significant.
7. Legal problems encountered in: closing roads through the site; relocation of cemeteries or Indian burial grounds; the proximity of schools

or churches; national monuments or historic sites within the proposed site; relocation of public or private utility easements; obtaining clear title to the oil, gas, and mineral rights as well as the land; court condemnation procedures; the ability of the municipality to comply with the Federal Uniform Land Acquisition and Relocation Act of 1970; and ultimate disposition of material cleared from the site. Muskegon County, Michigan encountered all these problems in developing their system.[53] The time consuming solution of such problems must be emphasized.

Water and Water Law

Many legal and ecological factors are involved in the decision to discharge wastewaters to the land rather than to streams. Both direct and secondary effects on flow regimen, water rights, and groundwater pollution must be considered.

Water Regimen and Secondary Effects.

The nature and quantity of receiving waters must be carefully evaluated prior to diverting the effluent. Elimination of direct wastewater discharges to a stream can unbalance the flow regimen associated with downstream beneficial uses, inhibit desirable dilution of waste discharge, and interfere with the moderation of thermal water discharges. If the land application site is outside the basin of origin of the water, the diversion can create an imbalance in the water resources of a watershed. The effluent from sewage treatment works constitutes the total or a major portion of seasonal low-flows in some streams. Tertiary treated wastewater returned to the stream may be of higher quality than the stream water itself. This is especially true during low flows on streams with significant acid mine drainage. In these streams, wastewater effluents have dilution value in maintaining stream flows and stream quality during low flow periods.

Wastewater discharges to streams can be important in moderating man-made and natural thermal conditions by maintaining receiving waters within optimum temperature ranges for the spawning and propagation of fish and aquatic biota.

The drought in western Montana during the summer of 1973 demonstrates the impact of dewatering trout streams.[54] As early as July 29, Prickly Pear Creek near Helena had been totally dewatered for half a mile by irrigation diversions and it "killed everything in that stretch--trout, forage fish, insect life, everything". Dead greyling and white fish were observed on the Big Hole River near Butte. The West Gallatin River, the Clark Fork River, and the Deer Lodge Creek were in critical condition.

Underdrains on a land treatment site can recover water that percolates through the soil. This water can be returned to the stream. The question remains whether the 50 percent normally lost to evapotranspiration represents the optimum use of the wastewater over the life of the project.

Where winter storage of effluents is required as part of a land treatment system, winter flow of the stream is reduced. This may be deleterious to fish and aquatic biota.

Water Law.

The basic rule of appropriative doctrine water law states that he who is "first in time is first in right", and so long as he continues to apply the water to a beneficial use, subsequent appropriators may not deprive him of his appropriation. A junior appropriator is entitled to have conditions on a stream remain as they were at the time he made his appropriation. A person desiring to appropriate water from a stream observes the available supply, taking into consideration all then existing appropriations, and then makes his economic decision as to whether enough water will be available, _under existing conditions_, to satisfy his requirements. If he perfects an appropriation, nothing may be done by a senior appropriator which would alter conditions on the stream to the detriment of the junior appropriator.

Raphael J. Moses, noted water lawyer, in a paper describing the legal aspects of land treatment in Colorado stated:[55]

> When a city, which has historically returned its sewage effluent to a stream, determines instead, to irrigate land with that water, three things happen. There is a change of type of use, there is an enlarged consumptive use, and there is a reduction in return flow.
>
> Let us see what the courts say about this:
>
> > "There is absolutely no question that decreed water right is valuable property; that it may be used, its use changed, its point of diversion relocated"...
> > "Equally well established, as we have repeatedly held, is the principle that junior appropriators have vested rights in the continuation of stream conditions as they existed at the time of their respective appropriations, and that subsequent to such appropriations they may successfully resist all proposed changes in points of diversion and use of water from that source which in any way materially injures or adversely affects their rights."[56]
>
> This quotation comes from the leading Colorado case of Farmers Canal and Reservoir Company v. Golden, decided in 1954. After the language quoted above, the Colorado Supreme Court cited seven other similar cases, five of which involved cities attempting to enlarge the use of a water right, all unsuccessfully. There are other similar Colorado cases not specifically cited in the Golden case.[57]

Cities have to have dependable water rights, and therefore they are usually among the most senior on the stream. It is good to be senior, but being very senior means that there are a great many juniors who will object, and promptly, if the regimen of the stream is changed.

At one time cities (and others) thought that they had a right to "use up" water once it was diverted. The courts disabused them of that concept, saying:

> "Once an appropriation has been diverted, used and returned, it becomes again a part of the stream in which junior appropriators below acquire a vested right."[58]

One thing should be made perfectly clear, however. For those who are able to go out and appropriate a reliable new source of water, there is absolutely no legal inhibition against appropriating that water for both municipal use and land treatment of secondary effluent. At the moment the appropriation is made that use is the most junior right on the stream and any subsequent appropriators will be junior and take the stream as they find it, with the right in existence to utilize the secondary effluent for land treatment. Therefore the subsequent juniors have no right to complain.

There are three other Colorado cases one should be aware of that deal directly with the right to re-use sewage effluent.

The earliest case is Pulaski Irrigating Ditch Company v. the City of Trinidad[59] in which the court said:

> "In 1892, a sewer system was completed by the City of Trinidad, and the sewage carried therein was emptied directly into the Las Animas

River. Very soon thereafter this disposal of the sewage was enjoined by the district court. Thereupon the city extended its sewers and discharged the sewage into settling pits on land adjoining the river. From the record it appears that a considerable part of the water content of the sewage seeped or ran back into the river, and soon became a part of the supply for the appropriations below the point of discharge.

In 1917 the city began the construction of two purification plants, and upon their completion proposed to sell the purified water to said Model Land & Irrigation Company; hence this suit.

There seems to be no substantial controversy over the facts, and the sole question presented for our consideration is as to the right of the city to sell the water.

Plaintiffs in error (the junior appropriators) contend that, inasmuch, as the water which escaped from the pits and ran into the river contributed to supply appropriations down the river, the city cannot now divert that water for use below the points where it has been in use for some years past. They contend also that the water, having performed the purpose for which it was diverted, must, under the law, be returned to the river from which it was taken.

[1] Defendents in error contend that "the application of water to domestic use is a use which consumes". They also contend, in effect, if not in words, that sewage is a thing which may be considered regardless of its constituents; and that the water resulting from its purification is salvage or developed water; that

> is, water produced from something which was not water.
>
> The first proposition is true only as to a part of the water applied to city uses. It is not true of water used in the sewers for the purpose of diluting and conveying away solid matter. This water in the sewers exists as fully as before it was used, but in connection with solid matter, which makes it unfit for further use, as it is. It has been used as a means of conveying matter, a merely mechanical use. That it may be used for irrigation before purification is not denied, but such use is highly objectionable for reasons well known. When it is purified, it is again the same element which was originally diverted. The separation will take place, to a large degree, if the sewage be allowed to stand, and that, too, without any external aid. That fact is conclusive that the sewage is not fundamentally different from water. A title by use is not acquired any more than it is in the case of water used for power purposes; in either case when the use has been completed, the right of the user terminates." ...
>
> "To turn this water back into the river will not increase the river's flow above what it would have been had the water not been diverted, and it is not therefore developed water. Applying the principle heretofore laid down. it seems clear that the water here in question does not belong to the city, and that it has no right to sell it."

Two very recent cases are Metropolitan Denver Sewage Disposal District v. Farmers Reservoir and Irrigation Company[60] and Denver v. Fulton Irrigating Ditch Company.[61] Each is a rather special fact situation and does not alter the case law referred to, but each should be mentioned.

Metropolitan is a case which held that someone returning sewage effluent to a stream has a right to change the the place of return, and is not governed by the rules involved in a change of point of diversion. It based its decision on early cases involving irrigation return flows, citing with approval Green Valley Ditch Company v. Schneider,[62] where the Court said:

> "Plaintiff's rights were limited and only attached to the water discharged from the Tegeler lateral, whatever that happened to be, after the defendents and cross-complainants had supplied their own wants and necessities. This does not vest her with any control over the ditches or laterals of appellants, or the water flowing therein, nor does it obligate appellants to continue or maintain conditions so as to supply plaintiff's appropriation of wastewater at any time or in any quantity, when acting in good faith."

citing other cases.[63]

Fulton confirmed the right under Colorado law of an appropriator of transmountain water to reuse that water for other than municipal purposes. Denver had brought water over from the Western Slope and wanted to trade sewage effluent to Coors for rights Coors owned on Clear Creek. The Court said Denver would have had a right to make the exchange except for an earlier contract with Fulton and others agreeing not to do so.

As you will note from the decision in the Fulton case, water imported from another basin holds a different and higher status. An importation made after junior appropriators perfect their claims adds water to the stream and the juniors, while permitted to utilize this windfall, have no right to demand its continued delivery.

> Although the citations here are Colorado cases for advising on the legal principles involved, I am of the opinion that the law is similar in all of the appropriation states, although the procedures may vary considerably.
>
> In conclusion, we find that land use of secondary effluent is legal provided the municipality replaces any diminution in return flow so that junior appropriators are not adversely affected by the new utilization of secondary effluent. The decision to inaugurate land use of secondary treatment requires some hard economic decisions.

Water Rights vs. Project Costs.

The water rights questions that need to be resolved, on a site by site basis according to each state's water laws, can be summarized as follows:

1. Have junior appropriators established vested rights in the effluent return flow?
2. What portion of the present and future effluent return flow originates from newly purchased water for which dominion over the return flow can be maintained, thereby allowing total consumptive use?
3. What portion of the effluent return flow originates from transbasin diversions which allow its reuse?
4. Were stipulations applied to the contract or decree which control the quantity or type of

reuse or forbid reuse?

5. If a private land application system is being considered, does the water procurement contract or water service agreement stipulate that the municipality maintains ownership of the sewer return flow?
6. Will the enlarged use of water due to land application of effluents adversely affect the water rights of junior appropriators?
7. Can the use of the effluent for the intended land application be legally defended as a beneficial use?
8. What will be the legal status of groundwater return flow from the land treatment site?
9. What portion of the return flow from an underdrained land treatment site can be used for water rights replacement?
10. Are trades of direct flow rights and storage rights legally available to reduce the impact on junior appropriators?

The answers to these questions will indicate what amount of water, of a priority at least as senior as the priority it is diverting, the municipality must leave in the stream to satisfy the water rights of junior appropriators. The answers will also indicate which engineering alternatives are available to minimize the water rights replacement costs. Water rights of a seniority adequate for municipal supply are difficult to obtain and command a high price. Although a city can condemn such a right, condemnation is the most expensive method of obtaining the right. The first step in any consideration of land treatment should therefore be consultation with a water rights lawyer or the State Engineer. The impact of the cost of water rights replacement may preclude the need to consider the cost effectiveness of land treatment any further.

A partial solution to the impact on summer direct flow water rights may be to store winter discharges, treat them in conjunction with summer effluent flows, recollect the percolation water in underdrains, and return it to surface streams. This could satisfy summer direct flow rights not belonging to the municipality. The hydraulic loading rate of the site is adjusted to provide for an underdrain return flow equivalent to that formerly discharged directly to the stream. Winter storage water is used to counterbalance evapotranspiration losses, leaving no net change in summer discharge flow. The impact to winter flow water rights, such as storage rights, should be easier to negotiate and less expensive to replace than summer direct flow rights.

This approach can also have an impact on groundwater rights. Reduced treatment efficiency due to high hydraulic loading rates can result in groundwater pollution from nitrates. There can be secondary environmental impacts on the stream from discontinuing winter discharges.

The Denver Regional Council of Governments in their study of areawide waste treatment management for the Denver metropolitan area estimated that, should land treatment be used exclusively, 365,000 acre feet/year of water rights would have to be replaced at a capitalized cost of $365 million dollars. It is doubtful that much water would even be available. They would also have to locate 99,100 acres of land suitable for treatment of the effluents.[64]

Water rights problems and the financing of replacement water are also encountered in selling the effluent to farmers. The farmers would treat the effluent by applying it to their own crops on their own land. The effluent may not belong to the municipality, or receipts from the sale of effluent may not cover the cost of water rights replacement. The APWA survey concluded that "sale of effluent for beneficial use has been generally unsuccessful. Few examples were found where a public agency had been able to obtain more than a token payment for supplying treated effluent". They also concluded that well trained personnel, aware of the need for careful operation of the systems, were required.[65] Concern was also expressed that farmers could tend to forget the special requirements of effluent wastewaters and create pollution problems that the municipality remains legally responsible for. Larger systems are therefore best kept under the total control of the dischargers.

Lease of effluents or lease of the land for the treatment site also have drawbacks. As the area develops in the future, the farmer or irrigation district may decide to sell the land at the appreciated value, and leave the municipality holding the wastewater. This is what happened in California to the Orange County Sanitation District. The Talbert Wastewater Irrigation District, which had been formed in 1957, had totally sold out to developers by 1964.[66] Pennsylvania has found that relatively few farmers have been willing to accept the long term commitment that is necessary to implement a system.[67] Farmers will probably only accept the amount of water required for maximum crop yield, rather than the optimum hydraulic loading for maximum treatment efficiency and minimum land requirement. The land requirement in the former case is greater. Design, construction and monitoring costs for a multiplicity of independent systems will be larger than for a smaller number of larger systems.

Muskegon County, Michigan decided to procure all the land required and thereby maintain total control of the treatment site.[68] This was also the conclusion arrived at by the Metropolitan Sanitary District of Greater Chicago in regards to their Fulton County sludge application site.[69] Section 212 of the Federal Water Pollution Control Act Amendments of 1972 provides the incentive that land procured for actual treatment of wastewater at land treatment sites is eligible for 75 percent Federal cost sharing.

Groundwater Pollution.

The legal and environmental aspects of groundwater pollution must also be considered. The preceding discussion of the federal and state regulations indicate the intent to protect groundwater quality. States which have imposed groundwater quality requirements tend to adopt portions of the U.S. Public Health Service Drinking Water Standards or the Raw Surface Water Quality Criteria. This may seem quite conservative, but it must be remembered that there is little present understanding of the acute and chronic effects of pollution on man, animals, or plants, and that groundwater pollution residence times can approach 200 years.

The present lack of monitoring of land treatment sites shows an apparent lack of appreciation of the potential for groundwater pollution and that more stringent enforcement is needed. Groundwater pollution in association with land treatment sites is almost always the result of either management errors or inadequate design. It is, therefore, both unnecessary and avoidable, but proper design, management and monitoring must be made mandatory. State regulatory agencies which have the requisite authority fail to exercise it in many cases, thereby leading to crisis situations.

Fresno, California has nitrate pollution of its groundwater and San Bernadino and Riverside Counties have synthetic detergent pollution of groundwater from spreading of wastewater effluents.[70] In the "Montebello Incident" in California, a single slug of weedicide which passed through a sewage treatment plant and land treatment site resulted in non-potable groundwater due to tastes and odors which persisted for several years. The wells were located several miles from the land treatment site.

The nitrate level in the groundwater beneath the Lubbock, Texas land treatment site has reached 105 mg/1 (compared to the Drinking Water Standard of 45 mg/1) due to wastewater application rates much higher than the crop nitrate uptake rate.[71]

Application of 30 feet of effluent per year on a 60 acre site at Hobbs, New Mexico resulted in nitrate levels as high as 140 ppm and pollution of 20 to 30 wells in a 2 square mile area. The city, successfully sued to stop discharging the effluent on the site, must pump out the mound of polluted groundwater and must supply potable water to the owners of the polluted wells.[72]

A study in Runnels County, Texas found that in a few cases, both humans and animals were using water containing more than 1000 mg/l nitrate with no apparent ill effects.[73] In other areas of Runnels County, infant methemoglobinemia had resulted from using water with as little as 50 mg/l nitrate.

CHAPTER III

SOCIAL, ECONOMIC, AND MANAGEMENT CONSIDERATIONS

Public Acceptance

Even though a land treatment system may be the most cost-effective alternative, it may not be acceptable to the people it is intended to serve. This lack of acceptance may be based on real or unfounded fears. Therefore, public involvement in the concept must be initiated very early in the analysis, rather than after the study is complete. Some concise comments on what will be encountered are provided by John Dunbar of Purdue University:[74]

> Why People Resist Change
>
> - When the purpose is not made clear.
> - When they are not involved in the planning.
> - When an appeal is based on personal reasons (yours, not theirs).
> - When the values, norms, and habits of the people are ignored.
> - When there is fear of failure, i.e. that the goal may not be reached with the funds available.
> - When the cost (social and economic) is too high in relation to the benefits or when they believe the costs of an alternative method would be lower to secure the same results.
> - When the present situation seems satisfactory.

- When they think they may have to pay the costs for benefits someone else will receive.

To overcome this resistance, Dunbar suggests:

- Involve the people in the diagnostic and creative processes of decision making--they tend to understand and support what they create.
- Allow the people to blow off steam. Too often people pushing an idea try to move ahead "so fast that the opposition won't have a chance to organize".
- Be certain that people agree upon the goals and reasons for the change.
- Build a trusting climate.
- Provide the information needed for people to think intelligently.
- Keep people informed. They will get more intimately involved if they know the latest details.
- Provide them with the information on what would happen if the various alternatives were implemented (how they work, costs involved, benefits, who pays the costs, who benefits).
- Stimulate the people to react. Let the people know what is being considered from the earliest possible moment.

Dunbar concludes:

> By far the simplest way to get people to look favorably upon one alternative is to let them compare it with others so that they can tell which they deem most desirable. This takes some

> courage on the part of professionals and planners--and some faith in the judgement of the public. But if we don't have that, we haven't much faith in democracy.

Comments from Postlewait and Knudsen, regarding their experiences with the Muskegon, Michigan project, point up the truth in the above statements:[75]

- If we were requested to single out the main lesson to be learned from the Muskegon project, without hesitation, we would cite the problems of developing sound public relations.
- We found the general public to be suspicious and extremely credulous of the system and the imagined danger to their health, safety, and welfare.
- The technological attractiveness of a given area cannot, however, be given primary consideration for many reasons since site selection cannot be determined in the laboratory or on the planner's table. Present land use is of critical impact in the selection process, since public acceptance and cooperation will be substantially enhanced by selecting a site which is not being ideally utilized.
- Politicians in our area had a clear demonstration of the effects of an aroused public, since the Township Supervisor of one of the more populous townships was recalled from office, because he lead the township board into granting consent.
- Electoral consents obviously involve public acceptance and understanding and again point to the need for sound public relations.

- Anyone who has been involved in attempting to relocate a cemetery or an Indian burial ground can relate the emotional problems which result.

- [Regarding relocation] A neighboring community was not so fortunate, since they had to bodily carry out some elderly owners, all of which did not present a good public image.

- The Muskegon project site is located in what was a rural, sparsely populated farming area. In setting up the relocation phase of our project, we ran into a wall of distrust.

- If the Muskegon experience is at all typical, any land-use system which requires the relocation of property owners from the proposed site will meet with resistance from many persons who are to be moved. This is a definite social problem that must be considered in planning.

- While there were substantial doubts as to the project harbored by the residents in and around the site area, some of the unrest was settled by a suit the County instituted for a Declaratory Judgement against the opponents of the project.

The above comments indicate the scope of the public relations effort which can be anticipated in planning large land treatment projects. The APWA survey and the survey of Region VIII indicated that public acceptance of land treatment has been good if they are informed and the site is well managed. Financial support through the

Federal Uniform Land Acquisition and Relocation Act of 1970 can also help overcome relocation problems and public resistance by making eligible for Federal cost sharing certain personal relocation costs that may not otherwise be reimbursed.

Farmer-Operator Acceptance

If the land treatment project proposes the sale or lease of effluents to farmers, or the lease of the farm land for the application site with the farmer becoming the operator, another public relations effort is required. The attitude which will confront such projects was well summarized by a former Missouri leglislator:[76]

> Another problem is that a tradition of distrust has developed between rural and urban segments of our society. The farmer often feels that he has been ignored or taken advantage of, to the benefit of the big city. He feels that government is distant and that it is not at all responsive to his needs or concerns. He, therefore, has developed a scrutiny, and stubborn protection of his own interests are a necessity. This has made the commercial farmer a good businessman, and be assured that he will ask the most vigorous and probing questions. He may well be suspicious that lard application of treated municipal waste is another effort to solve city problems at the expense of the rural dweller. He will ask how this waste will compare to other systems in cost, nutrient value, and yield. Does the waste contain substances that will harm his soil or the value of his crop.

An example of this type of rural-urban conflict arose when the Denver Metro Sewage District approached the farmers in the Watkins and Bennett, Colorado area regarding the disposal of liquid sludge on their dry farmlands.[77] The Sewage District representatives were not adequately prepared for the probing questions raised and the project is now being reconsidered.

There are several alternative approaches that can be invaluable aids in presenting the concept of land treatment to farmers. Personnel from the State Agriculture Experiment Stations and the Agricultural Extension Service can be brought into the program in the early stages. They can anticipate the questions that will be asked, and determine which areas need more investigation. They also have a long standing rapport with the agricultural industry. If a concept or technique is new to a farming area, a pilot project conducted in conjunction with the Agriculture Experiment Station may be an invaluable tool in demonstrating the feasibility of the concept.

Economic and Cost Considerations

The costs involved in the land application of effluents are site specific and generalizations must be made with caution. The cost information obtained in the APWA survey is summarized by Pound and Crites.[78,79]

Capital costs and operating and maintenance costs reported in the literature, including the Pound and Crites reports, are usually the combined costs for the pretreatment and the land treatment portions of the system. This intermixing of costs and the additional factors of land purchase or lease, land value, water rights, and cost inflation factors makes capital cost comparisons extremely difficult. The wide range of costs attest to their site-specific nature. For example, the survey found that the pretreatment and spray irrigation annualized capital costs ranged from 19¢ to 92¢ per gallon per day, while the land costs ranged from $5 to $5,000 per acre. Pretreatment and land application operating and maintenance costs ranged from 2.7¢ to 11.6¢ per 1000 gallons of effluent. Site specific cost estimates will have to be developed for each proposed site rather than extrapolating cost estimates from one site to another.

EPA guidelines should be consulted to determine the costs, including land, eligible for federal construction grant cost sharing. Cost sharing of family relocation costs is covered in the Federal Uniform Land Acquisition and Relocation Act of 1970.

Environmental Considerations

Environmental considerations appear to be best handled through preparation of an Environmental Impact

Statement (EIS) in accordance with EPA guidelines. An EIS is required when Federal construction grant cost sharing is involved and significant environmental effects are anticipated or the environmental impact of an action is likely to be highly controversial.[80]

Management Considerations

Management considerations are both site-specific and dependent upon ownership of the land used for treatment. In Pennsylvania,[81] it was reported that management of the system is the deciding factor between success and failure for most land treatment facilities. It was found that adequate size and flexibility were frequently designed into the system; but, as a result of cost-cutting, the systems too often were poorly managed. New concepts and completely new orientations in terms of irrigation farm operations are required when managing irrigation systems for liquid waste disposal. Whereas farmers ordinarily manage their irrigation operations to maximize crop production, in wastewater irrigation the primary objective is to manage for adequate renovation of the wastewater; crop production is a secondary consideration. Myers reported that in Pennsylvania it was found that usually the municipality or company producing the effluent should own the land since no matter how conscientious a farmer is, it is difficult to convince him to irrigate a crop which already has received twice as much water as necessary for crop production. Wastewater disposal management requires application of maximum amounts of water on the land, not minimum amounts. Monitoring of the groundwater entering and leaving the renovation area is also an essential part of system management.

Regulatory personnel in Pennsylvania have found in that state that site management has been uniformly quite poor.[82] Maintenance personnel rarely visit the works, piping is broken, sprinklers clog or stop up, field areas are flooded, mosquito populations increase, soils are waterlogged, and the renovation field may be anaerobic. Rhindress reported that company managers often view spray irrigation and wastewater treatment as a liability to company operations and, therefore, consistently relegate project management to a very low priority. Maintenance of the site is normally the responsibility of the bottom man on the maintenance staff. Pennsylvania inspectors found evidence that no one had viewed some sites or made necessary repairs for long periods of time.[83] New York's experience appears to have been similar.[84] The impact of long term mismanagement at Hobbs, New Mexico was discussed in the section on groundwater pollution.

Pound and Crites have summarized some of the management aspects resulting from their national survey of the engineering aspects of land treatment.[85] They conclude:

> The management of an irrigation system is as important as the site selection and system design. It is vital that management personnel have a working knowledge of farming practices as well as principles of wastewater treatment. Important items in management include seasonal (often weekly) variation in operation, monitoring to establish removal efficiencies and to forecast build-ups of toxic compounds, and ongoing observations of the system to avoid problems of ponding, runoff, or mechanical breakdowns. The operation of a crop irrigation system must adjust to the changing demands (water and nutrient) of the crops ... Even with automated systems there should be an observer present daily to ensure a smooth operation. With manual systems, full-time operators are required ... The need for competent farm management cannot be overstressed.

These comments point out the importance of adequate planning and funding for proper site management. In some respects, the requirements are greater than standard physical-chemical-biological tertiary treatment since the site operators must be knowledgeable about both wastewater treatment and irrigation farming practices.

CHAPTER IV

ENGINEERING AND TECHNICAL CONSIDERATIONS

The primary purpose of land application of effluents is wastewater treatment through utilization of physical, chemical and biological soil characteristics. The site-specific nature of wastewater constituents, soil types, site topography, climate, hydrology, geology, and local agricultural practices limits the usefulness of generalized extrapolation of past practices into the engineering design for a specific site. This discussion will identify the major engineering decisions that need to be made. The state of knowledge regarding various design parameters will be indicated and their relationship to design decisions explained.

A prerequisite to consideration of the engineering factors involved in land treatment of municipal effluents in the western states is the determination of effluent ownership based on western water law. The water rights replacement costs due to evapotranspiration losses or losses to groundwater during land treatment may preclude land treatment from being a cost-effective alternative, thereby making detailed consideration of the engineering factors unnecessary.

Pretreatment Requirements

Almost all municipal land treatment systems have the equivalent of secondary treatment and disinfection as the minimum pretreatment. Secondary treatment systems usually consist of trickling filters, activated sludge systems, or lagoons followed by chlorination. The pretreatment requirements are based on health and hygiene aspects, odor reduction, and improvement of operational efficiency and reliability. If significant quantities of industrial wastes having toxic metals or organics are found in a municipal effluent, the pretreatment regulations promulgated by the EPA should be imposed on the responsible industries. This results in treatment of toxic substances where it is most effective--at the source. Pretreatment reduces the transmission of toxic substances to the crops raised on the site, or a build-up of toxic levels in the soil on the site. The rate of transmission of toxic metals and organics through the food chain and the level of crop and animal toxicity to trace elements are two of the major unknown effects of land treatment today.

Land application of industrial effluents has been restricted primarily to the food processing industry, the pulp and paper industry, and the dairy industry.[86] Three main reasons for the development of the technique in these industries are: (1) the location of the operations in rural areas with access to suitable land, (2) the nontoxic and easily biodegradable nature of the wastewater, and (3) the seasonal nature of the food processing industry. These effluents are high in BOD and suspended solids and void of pathogens. Consequently, pretreatment can be minimized, and usually is aimed at eliminating operating difficulties. Screening is used to prevent spray head plugging. Lagoons are used for BOD treatment and wastewater flow and strength equilization, but detention time in the lagoons is minimized to prevent odor problems from occurring. Many sites prefer to spray direct with screening as the only pretreatment.

Effluent Characteristics

Determination of the physical, chemical, biological, and flow rate characteristics of the effluent to be treated is required for the consideration of land treatment alternatives. Of particular importance is the determination of total nitrogen, toxic metals and toxic organics. Total nitrogen usually is the controlling factor in hydraulic loading of municipal sites and determines the land areas required. Toxic metals and organics are important to both municipal and industrial treatment sites due to the acute and chronic effects on the biota performing the treatment. Peak flow characteristics determine the land area required for systems without storage capacity.

A sample analysis of a municipal effluent (Denver) is shown in Table I. The data show typical constituent concentrations in Denver effluents[87] and the projected concentration in the root zone, assuming a 50 percent evapotranspiration loss and no uptake by plants or modification by soil organisms. The raw surface water criteria used for public water supplies,[88] the preliminary EPA groundwater criteria,[89] and irrigation water criteria [90] are presented for comparison to the effluent and projected root zone constituent concentrations.

The following constituents would create groundwater pollution problems if they were leached from the root zone without dilution or treatment by the crops or soil: Coliform, TDS, Nitrate, Sodium, Chromium, Fluoride, Iron, Lead, Manganese, CCE, CAE, Sulfate, Phenols, and perhaps Chloride. The fate of these constituents will be discussed in later sections.

The boron concentration in Denver's effluent is unknown. Boron is toxic to certain crops in the 0.7 to 1.2 mg/1 concentrations typically found in municipal effluents.[91] Boron concentrations in effluent are primarily derived from the increasing use of low and no-phosphate detergents containing borax and perborate. Molybdenum in the effluent is 20 times the maximum

TABLE I

SAMPLE MUNICIPAL WASTEWATER ANALYSIS

Constituent (mg/l except as noted)	Surface Water Criteria	Preliminary EPA Groundwater Criteria	Irrigation Water Criteria	Denver Secondary Effluent	Root Zone Concentration E.T. = 50%
Physical:					
SS	-	-	-	98	196
Biological: (MPN/100 ml)					
Coliform	10,000	-	-	160,000	-
Fecal Coliform	2,000	-	-	26,000	-
Chemical:					
TDS	500	-	variable	480	960
pH, units	6.0-8.5	-	-	7.7	-
BOD	-	-	-	24	48
COD	-	-	-	62	124
Total N	-	-	-	28.2	56.4
Nitrate N	10	10	-	trace	< 56.4
Ammonia N	0.5	-	-	17.5	variable
Phosphate	-	-	-	8.7	17.4
Sodium	-	270	-	155	310
Potassium	-	-	-	unknown	unknown
Calcium	-	-	-	62	124
Magnesium	-	-	-	10.6	21.2
SAR	-	-	variable	4.8	-
Boron	1.0	-	0.75	unknown	unknown
Arsenic	0.05	0.1	1.0	0.003	0.006
Barium	1.0	1.0	-	0.192	0.384
Cadmium	0.01	0.01	.005	< 0.001	< 0.002

TABLE I (continued)

Constituent (mg/l except as noted)	Surface Water Criteria	Preliminary EPA Groundwater Criteria	Irrigation Water Criteria	Denver Secondary Effluent	Root Zone Concentration E.T. = 50%
Chloride	250	250	-	120	240
Chromium +6	0.05	0.05	5.0	0.05	0.10
Copper	1.0	1.0	0.2	0.07	0.14
Cyanide	0.2	0.2	-	< 0.01	< 0.02
Fluoride	1.3	1.1	-	1.09	2.18
Iron	0.3	0.3	-	3.0	6.0
Lead	0.05	0.05	5.0	0.082	0.164
Manganese	0.05	0.05	2.0	0.075	0.15
Mercury	-	0.005	-	-	-
MBAS	0.5	0.5	-	0.116	0.232
CCE	0.15	0.3	-	2.478	4.96
CAE	-	1.5	-	1.185	2.37
Selenium	0.01	0.01	0.05	< 0.001	< 0.002
Silver	0.05	0.05	-	0.008	0.016
Sulfate	250	250	-	168	336
Zinc	5	5	5.0	0.185	0.37
Phenols	0.001	-	-	0.01	0.02
Specific Conductance	-	-	variable	1.03	-
Molybdenum	-	-	0.005	0.1	0.2
Nickel	-	-	0.5	0.12	0.24
Aluminum	-	-	1.0	0.16	0.32
Beryllium	-	-	0.5	-	-
Cobalt	-	-	0.2	< 0.001	< 0.002
Lithium	-	-	5.0	-	-
Tin	-	-	-	0.003	0.006
Tungsten	-	-	-	0.147	0.294
Vanadium	-	-	10	< 0.001	< 0.002

recommended levels for irrigation water. Molybdenum may concentrate in plants in quantities toxic to cattle.

Site Requirements and Selection

The following factors should be considered when evaluating potential land treatment sites: location, topography, geology, hydrology, agronomy, and soils. All of these factors are site specific and have interdependent relationships affecting the engineering design. The significance of various physical and geochemical factors to be considered when selecting irrigation sites vary depending on: (a) the quality of the wastewater to be applied, (b) the acreage required, (c) the amount and duration of the wastewater application, (d) the water quality standards to be met for the receiving body of water, (e) climate, (f) other uses to be made of the site, (g) the irrigation season, and (h) the management considerations.[92]

The ultimate project success or failure depends on sound engineering judgement by qualified, experienced people in several engineering disciplines. The State of Pennsylvania Spray Irrigation Manual requires a soil scientist, geologist and hydrogeologist to complete and approve their respective portions of the permit application forms.[93] The engineering decisions required for site selection will be briefly discussed in the following paragraphs.

Location.

Engineering factors, as well as the legal and social factors discussed earlier, must be considered when locating a land treatment site. Factors not directly related to treatment site efficiency include water rights, zoning, adjacent land use, area for future expansion, availability of winter storage reservoir sites, and the tradeoffs between pumping cost and land cost as the site becomes more remote from the secondary treatment plant.

Topography.

Site topography must be adaptable to the agricultural operations to be performed. Sloping sites can be terraced and provided with contour ditches or leveled to increase detention storage and infiltration. Leveling is costly and may expose undesirable soils. Overland flow should be limited to prevent uneven spatial infiltration which can result in inconsistent treatment. Surface runoff must be controlled to prevent pollution of adjacent surface waters. Slope will also affect storm runoff and erosion on the site. Surface runoff retention for a storm of a specified frequency and duration may be required to prevent surface water pollution. Groundwater mounds below land treatment sites located on steep slopes can create problems due to groundwater reappearance as new springs or swamps in adjoining areas. Areas with high water tables may also have groundwater mounding problems. Drainage ditches, tile fields, or drainage wells are then required to maintain a zone of aeration and to control groundwater flow.

Geology.

The depth to bedrock and the amount of folding, fracturing and faulting of the bedrock will affect the site suitability. Such features reduce treatment efficiency by short-circuiting percolating wastewater to the groundwater. Glacial deposits such as the typical ground moraine can have fragipan developed high in the soil. This can create a seasonal high water table. Sands and gravels typical of outwash plains and valley fills can have permeabilities too high to give adequate residence time for wastewater renovation.[94]

Climate and Evapotranspiration.

Factors such as annual precipitation and its seasonal distribution, humidity, wind velocity, and temperature range will affect both the evapotranspiration of the site and the type of crop that can be grown. The length of the growing season will affect crop choice, crop water demand, and the required volume of winter storage or the need for alternate methods of winter disposal. Wind velocity, direction and duration will affect the size and location of buffer zones and the useable irrigation season. The frequency, amount, and duration of precipitation can affect groundwater quality by leaching mobile pollutants out of the root zone, result in surface runoff, or raise the soil moisture to field capacity or even saturation.

In arid climates, effluent is depleted mainly by evapotranspiration rather than percolation. Prolonged irrigation with low application rates would result in a dissolved solids build-up in the root zone. These salts would have to be leached to prevent crop damage, and this would result in groundwater pollution. Intercepting the leachate with tile fields would only exchange surface water pollution for groundwater pollution.

Application rates combined with precipitation must exceed evapotranspiration rates to give continuous leaching of soluble salts. The frequency and duration of the applications must also be controlled to allow adequate detention time in the root zone for the crop uptake of mobile nutrients such as nitrates. Thus it can be seen that the application of effluent is an ever changing function of climate, precipitation, evapotranspiration, infiltration, percolation, crop nitrate uptake rate, leaching rate, denitrification rate, field capacity of the soil, root zone depth, groundwater depth, and aquifer transmissibility. Effluent application is a multivariable function which must be continually adjusted to prevent surface runoff, groundwater pollution and crop toxicity. On large sites this could require extensive instrumentation and monitoring, and computer modeling of site characteristics to predict and maintain proper site management.

Application Rates and Land Requirements.

Three loading rates are of concern in site selection and design. They are the liquid loading rate, the nitrogen loading rate and the organic loading rate.

Organic loading rates of up to 7000 lbs BOD/acre/year have been successfully used.[95] The acceptable rate is site specific, but is probably not the controlling function for the application of secondary effluents from municipalities. For industrial effluents the organic loading rate may be the controlling function. The organic loading rate is also a factor in selecting a drying out/decomposition period between applications. Excessive organic loading may reduce the infiltration rate and cause ponding and anaerobic soil conditions.

The liquid loading rate (inches of effluent per week) is affected by the variable conditions described in the previous section. If effluent constituents are in sufficiently low concentrations, the liquid loading rate is adjusted to the seasonal evapotranspiration and percolation rates of the crop and soil. Ponding should be avoided. Liquid loading rates are both site specific and seasonally variable and are best determined in consultation with soils or agriculture experts.

To prevent surface runoff and ponding, the application rate (inches of effluent per hour) should not exceed the infiltration rate of the soil. This requires adjustment of the application duration and frequency with season, precipitation and crop conditions. Design rates should not be based solely on percolation tests because these typically indicate infiltration rates that are much higher than can be expected under operating conditions.[96] The rate of application itself is set by the nozzle size, spray area and the water pressure and is relatively fixed.

The nitrogen loading rate (lbs N/acre/year) is the controlling function where groundwater nitrate pollution is of concern. The nitrogen loading rate depends on the crop type, the crop seasonal nitrate uptake, the soil type, the degree of crop removal at harvest, the amount of denitrification in the soil, and the amount of nitrate allowed to leach to the groundwater or the underdrains. Once again, the application rate (inches of effluent per hour) should not exceed the soil infiltration rate. The application should preferably match the seasonal nitrate requirements of the crop. Determining and maintaining this nitrate balance is one of the main challenges in land treatment and can also be one of its weakest links. Denitrification in the soil is just beginning to be understood, and is not presently a reliable process for nitrate removal. Nitrate removal efficiency is affected by precipitation since a heavy rain after a spray cycle can leach nitrates below the root zone.

Once the controlling loading rate has been established, the approximate acreage necessary for irrigation can be calculated for a known wastewater flow rate. For emergencies, an alternate area should be available. If winter storage is planned, the area must be sufficient for application of the daily flow plus a proportion of the stored effluent.

Infiltration Rate and Drying Cycle.

The prediction of infiltration rates for disposal fields is more difficult than the prediction of normal infiltration rates for high quality water. This is due to surface accumulation of suspended solids, bacterial action in the soil, and cation effects on the soil structure. The best way to determine the attainable infiltration rates for land treatment is through field trials using the actual wastewater and application system.[97]

Drying periods between applications are required to allow desiccation and aerobic biological action to restore infiltration capacity. In situations where coarse soil, gravel, or mulch overlays a finer soil, the restoration of the infiltration rate may be extremely slow due to the filtration occurring lower in the soil profile where desiccation and biological processes are impeded. The optimum combination of infiltration rate and drying period is site specific and can best be evaluated by field trials.

Vegetation improves infiltration rate by protecting the soil against compaction by direct impact of waterdrops during irrigation. Climate affects infiltration rates through the effect of temperature on wastewater viscosity and through the effects of rain and temperature on the recovery of infiltration rates during drying. Temperature affects the rate of soil biological processes for organic decomposition. There are systems in which the infiltration rate remains acceptable after 60 years of operation.[98]

Soils.

Important soil characteristics include drainability, ion exchange capacity, organic content, chemical constituents, and subsoil mineralization. The U.S. Soil Conservation Service has soil maps delineating soil physical characteristics to depths of 5 feet for most parts of the United States.[99] Drainage characteristics are important as they relate to the soil's ability to retain effluent in the root zone. This is largely determined by the relative percentages of sand, silt, and clay. Permeability of the soil and the presence of impermeable layers are also important.

Ion exchange capacity, derived primarily from clay and organic material, is relied upon to retain and store exchangeable waste constituents until they can be assimilated by the soil biological system. Ion exchange capacity is also relied upon to indefinitely store toxic metals, trace elements, and excess phosphorus. Organic matter is desirable both for its ion exchange capacity and as a carbon source for denitrification.

Soil chemical characteristics of importance are salinity, alkalinity, nutrient level, pH, conductivity, and sodium adsorption ratio due to their effects on crops, physical characteristics of the soil, and groundwater pollution. Subsoil mineralization affects groundwater pollution due to solution of salt or nitrate deposits as the effluent percolates through the soil.

Adequate soil depth is important for crop root development, for retention of wastewater components, and for bacterial action. Root activity is generally limited to 4 or 5 feet, but roots of plants such as alfalfa can reach 9 feet or more. Soil retention capacity for wastewater components such as phosphorus, heavy metals, and viruses is a function of residence time in the soil. Parizek of Pennsylvania State University recommends a minimum of 20 feet of soil to allow for soil thickness variations, ponding, animal burrows, and as a margin of safety against pollutant breakthroughs when operational mistakes are made.[100]

Groundwater and Underdrains.

Once wastewater reaches the water table, only minimal renovation can be expected. Wastewater reaching the water table can be expected to move laterally away from the site with dilution and dispersion being the only continuing renovative processes. Vertical mixing and vertical dispersion into the water table normally will be minimal.[101] Groundwater monitoring points must take this into account by monitoring at different levels.

The basic groundwater considerations are depth and seasonal variation of the water table, rate and direction of flow, location of natural groundwater discharge points, groundwater quality and the effect of the groundwater mound that may build up under the site.

The depth to the water table is important because it is a measure of the zone of aeration in which renovation takes place. Percolate wastewater recharging groundwater will create a groundwater mound beneath the site. The size of the mound will depend on soil permeability and the hydraulic loading rate. A low permeability and high water table may cause the mound to intersect the land surface resulting in poor renovation, swampy areas, and odorous conditions. Groundwater mounds can also alter the direction of groundwater flow from the site. The groundwater mound should be maintained below the active root zone. Knowledge of groundwater flow direction and rate are important for establishing monitoring points above and below the site to determine the pollution increment added to groundwater.

The groundwater table can be controlled by installation of an underdrainage system or pumping wells. If the water table or an impermeable layer is relatively close to the surface, tile fields or drainage ditches are usually the most cost effective means of controlling groundwater levels. If the aquifer is deep or unconfined, pumping wells may be required to control the groundwater levels. Underdrainage is also useful to alleviate the water rights problem by returning percolate water to the surface stream.

Storage Reservoirs and Lagoons.

Storage reservoirs and lagoons are used to hold wastewater effluent flow in areas without winter growing seasons, since sites with designs based on nitrogen loading rates depend on crops for the ultimate fate of the nitrates. Lagoons also serve to equalize effluent flow and effluent pollutant strength variations.

The major factors involved in the determination of the required reservoir capacity is the winter effluent flow volume, affected water rights, reservoir losses, quantity and seasonal distribution of annual precipitation, and crop growing season. The crop selected to be grown on the land treatment site has a major impact on reservoir size. For example, an annual such as corn may have a water and nutrient demand for only 3 to 4 months, whereas a perennial such as reed canary grass can have a water and nutrient demand of 7 to 8 months. The annualized savings from reducing the reservoir size by a factor of two may more than offset the reduced forage value of reed canary grass. Reservoir size may be influenced by the water rights considerations as discussed previously. Reservoir sizing should allow for precipitation and evaporation, Seepage losses from the reservoir should be controlled since seepage can result in groundwater pollution.

The use of storage reservoirs or lagoons has other potential problems. Effluent reservoirs can have odorous conditions during spring and fall turnover or from malodorous algae blooms. In colder climates or higher mountain elevations, lagoons are affected by longer winters with thick ice or snow cover, lower average summer temperatures, and reduced oxygen solubility. Continuous or periodic aeration by mechanical means may be required to aleviate or prevent odorous conditions.

Algal growth in storage reservoirs or lagoons can create operational problems by plugging irrigation systems. A simple, effective algae removal system is not yet available. Selective algaecides and rock filters with subsurface drawoff are being developed. The chlorine demand of algae, ammonia and BOD can interfere with the chlorination of lagoon effluents. The effect of chlorine on pathogenic viruses in the presence of algae, ammonia, and residual organics is not known. High residual chlorine content in the effluent can affect the soil biota responsible for effluent treatment.

Pilot Systems.

The performance of a land treatment system depends so much on local site specific conditions of climate, soil, and hydrogeology, that pilot systems should precede any large development. The best way to determine the attainable seasonal infiltration rates for a land application system is through field trials, using the actual wastewater and application system.[102] Problems with the variability in the surface and the infiltration rate can then be worked out before final design. The treatment effectiveness and potential build-up of salts can be analyzed. Present day technology is not sufficient for predicting the quality of irrigation return flow. Thus, there is a real problem in making long-range projections on water quality from irrigation projects. The real critical problem is defining the variability in subsurface return flows for large areas.[103]

Fate of Wastewater Constituents

The fate of wastewater constituents is an important factor in the consideration of land treatment and in the selection of land treatment sites. The five major ultimate fates of the constituents are: (1) volatilization and release to the atmosphere, (2) runoff to surface waters, (3) uptake by and removal with crops, (4) temporary or permanent retention in the soil, and (5) leaching to groundwater. The fate of each constituent is dependent on the physical, chemical, and biological characteristics of the constituent and the soil, and the interaction between the two. Some of the interactions can be controlled by man, others cannot.

Physical Constituents.

Temperature of the effluent is not a problem unless it is so high as to be deleterious to the vegetation and biota. Color has little effect, if any.[104] Odors in wastewaters are not normally a problem on well managed sites where the storage lagoons and the soil are not allowed to become anaerobic. Certain volatile industrial compounds can cause noxious odors when released to the atmosphere. These can best be controlled through pretreatment requirements.

Suspended solids are filtered out during percolation through the soil. Almost complete retention is achieved within a few inches to a few feet of travel.[105] A major fraction of the suspended solids in municipal effluents are volatile and can be biochemically oxidized. Management of the resultant biochemical oxygen demand is a big factor in the successful operation of the system. Insufficient available oxygen in the soil will cause the site to go anaerobic with the associated odors and shift in biological and chemical processes. Information from practical experiences with land disposal of wastewaters shows a wide divergence in the amount of biodegradable solids which can be applied to the soil without inducing soil clogging and anaerobic conditions. Thomas cites experiences of successful BOD loadings (site specific) ranging from 2 lbs/acre/day to 200 lbs/acre/day.[106] Typical suspended solids concentrations found in municipal secondary effluents should therefore have little effect on the operation of well designed and well managed sites. The Denver effluent cited earlier, with a suspended solids of 98 mg/l and 70% volatile solids, when applied at a rate of 2 inches per week, would result in a total suspended solids loading of 6.3 lbs/acre/day and a volatile suspended solids loading of 4.4 lbs/acre/day.

Nonbiodegradable solids in the effluent accumulate in the soil, however the quantity which accumulates is a very minor addition to the total soil volume.[107]

Industrial effluents with extremely high BOD and suspended solids must be analyzed on a site by site basis to see if they would create unusual problems.

Organics.

Solid and dissolved organic constituents in wastewater effluents include proteins, carbohydrates, fats and oils, surfactants, phenols, and trace organic chemicals such as pesticides, insecticides, and herbicides. The relative concentrations of these constituents is determined through tests such as COD, BOD, CCE, CAE, and MBAS. Very little is known about the chemical analysis or synergestic effects of organic compounds in the combinations and quantities found in secondary effluent.[108] The readily biodegradable organics (proteins, carbohydrates, nucleic acids, amino sugars, etc.), as measured by the BOD test, should cause no problems for well managed sites when applied in the quantities normally found in secondary effluent. The remaining organic compounds, called refactory organics (phenols, surfactants, hydrocarbons, pesticides, herbicides, etc.), are normally present in small quantities in secondary effluent. The refactory organic content is estimated by the difference between the COD and BOD measurements. Some refactory organics have persistent toxicity, and very little is known about their ultimate fate after they reach the soil, their rate of biodegradation, or their acute and chronic physiological effects.[109] The most effective control of toxic organics is the imposition of the industrial pretreatment requirements promulgated by the EPA; however this will not prevent adverse effects from accidents or clandestine dumping by either industry or the public.

Major Inorganic Ions.

The major inorganic ions in wastewater include calcium, magnesium, sodium, potassium, chloride, sulfate, and carbonates. The interrelationships among them as measured by total dissolved solids, alkalinity, hardness, pH, sodium adsorption ratio, and electrical conductivity are important in the consideration of land treatment. Each factor is site specific and must be evaluated for the conditions under consideration.

The most important soil characteristic in regard to inorganic ions is the ion exchange capacity of the soil. The higher the ion exchange capacity, the greater the purification ability. Increased exchange capacity means increased clay and organic content and decreased water permeability. Therefore an important aspect of site selection is the balance between the ion exchange capacity and permeability.

The relative balance between evapotranspiration, rainfall, and irrigation rate will influence the build-up of the total dissolved salts in the soil and thus the frequency, rate, and concentration at which they are leached to groundwater or underdrains. With evapotranspiration of 50% of the applied effluent, the effective concentration of salts in the effluent in the root zone is doubled since nearly pure water is evaporated or transpired. The subsequent rate at which the applied irrigation water plus rainfall exceeds field capacity will determine the level of pollution of groundwater, or surface waters where underdrains are used.

One of the major ion exchange reactions in the soil is the exchange of sodium for calcium. It is of particular importance because of the adverse effect upon the physical structure of soils which contain clay. The soil dispersive effect retards the movement of water and the leaching of salts. The effect is dependent upon the relative milliequivalent per liter concentrations of the sodium, calcium, and magnesium cations as defined in the Sodium Adsorption Ratio (SAR):

$$SAR = \frac{Na}{\left(\frac{Ca+Mg}{2}\right)^{1/2}}$$

Anions such as carbonates and sulfates, which precipitate either calcium or magnesium, will affect the sodium adsorption ratio.[110] The exchangeable sodium percentage (ESP) in the soil, the soil pH, and the relative concentrations of cations and anions are also factors affecting the SAR.[111]

Electrical Conductivity indicates the total dissolved salts concentration and furnishes an approximate indication of the overall mineral quality of the water. Highly saline or highly bicarbonate concentrations can affect permeability significantly.[112] The total effect of all these parameters is best determined by field studies.

Sodium can affect the osmotic action in some plants and prevent water uptake. Sodium has been shown to be a problem with cardiac patients, and is therefore of concern since it passes essentially unaffected through the soil treatment system.[113] Sodium and chloride are toxic to some plants and can be concentrated and absorbed through the leaves during spray irrigation.

Essential ions such as calcium, magnesium, potassium and sulfate may deter growth if the total or relative concentrations are out of balance. Plants vary in their tolerance to high concentrations of calcium, magnesium, potassium and sulfate.[114] High bicarbonate may induce iron chlorosis.[115]

It can be concluded that analysis of the wastewater for cation and anion concentrations and their relative concentrations is a necessary prerequisite to proper soil and crop selection. Soil type will affect the mobility of the divalent cations and permeability. Cation and anion effects on long term permeability must be considered. Rainfall plus the quantity and frequency of application of effluents will affect the total dissolved salts concentration of groundwater or return flow and their transient concentration characteristics. Sodium, chlorides, sulfates, and the total dissolved salts are highly mobile in the soil and their effect on groundwater pollution must be considered since evapotranspiration can create high concentrations in the root zone, as shown in Table I.

Nutrients.

Municipal effluents contain nitrogen in organic, ammonia, nitrite, and nitrate form. The relative amount is a function of the freshness of the effluents. Industrial effluents can have varying amounts of nitrogen, depending on the process involved. Some industrial effluents may have nitrogen levels too low to support biological activity.

The fate of nitrogen compounds applied to the soil are: volatilization to the atmosphere, runoff to surface waters, uptake by and removal with crops, temporary retention in the soil, and leached to groundwater. The primary biological processes involved are the decomposition of organic nitrogen to ammonia, nitrification of ammonia to nitrite and then to nitrate, and the denitrification of nitrate to nitrogen gas or nitrous oxides. Nitrification is an aerobic process requiring only oxygen. Denitrification is an anaerobic process requiring the absence of oxygen and the presence of a carbon source.

Organic nitrogen is filtered out in the soil and decomposed to ammonium nitrogen. The ammonium ion is then adsorbed in the soil by ion exchange. In the presence of clay minerals and certain organic soil fractions, ammonium ions are preferentially adsorbed. These adsorbed ions can be held tightly and may be resistant to leaching.[116] The ammonia is then available to some plants for direct uptake or for nitrification.

Nitrate nitrogen is mobile. Nitrate that is not taken up by a crop or denitrified will leach to groundwater with the next rain or irrigation. The nitrogen loading rate therefore becomes the controlling factor on wastewaters with high nitrogen content. For example, the effluent in Table I has a total nitrogen content of 28 mg/l which becomes 56 mg/l when concentrated in the root zone by 50% evapotranspiration. If pollution requirements were to require no more than 10 mg/l of nitrogen (NO_3-N) in nitrate form in the groundwater or underdrain water, 46 mg/l of nitrogen would have to be removed.

Soil pH is usually close to neutral and therefore volatilization of ammonia is insignificant. Management of denitrification in the soil is not well understood and therefore the process cannot be depended upon for nitrogen removal. Studies at Pennsylvania State University concluded that "although microbial denitrification appears to be a potential solution to the problem of nitrogen elimination from soil and waters, the available knowledge is still fragmentary and inadequate in order to manage efficiently the denitrification process in the various ecosystems".[117] There are problems in sustaining nitrification and denitrification processes in the same soil profile, and providing a source of carbon in the anaerobic zone in an unsaturated soil. Lance, in an excellent summary of the state of the art on denitrification,[118] concluded that the process offers tremendous potential when proper management is developed.

Crop uptake, therefore, is the only dependable nitrogen removal mechanism presently available. To minimize the land treatment area required, a crop should be selected for maximum nitrate nitrogen uptake and a fairly constant nitrate nitrogen demand. For soils where the maximum annual hydraulic loading rate is the controlling factor, crop selection would be based on the nitrogen loading associated with the selected hydraulic loading rate. To minimize the winter storage, the crop should also have a long growing season. The wastewater application rate should be adjusted to the seasonal nitrate uptake rate of the crop, since applying the wastewater in too large increments risks leaching the nitrates out of the root zone before crop uptake occurs. The failure to balance wastewater application with crop nitrate uptake has led to significant groundwater nitrate pollution below land application sites at locations such as Lubbock, Texas; Hobbs, New Mexico; and Fresno, California.

The amount of phosphorus that can be adsorbed by the soil is site specific as to the type of soils and soil depth. Since the effluent contains more phosphorus than the crop can absorb, the capability of the soil to retain and fix phosphorus is important to the site treatment efficiency. Phosphorus adsorption follows the Langmuir adsorption isotherm, and the maximum quantity of adsorption would not be reached except for very high levels of phosphorus in solution. An analysis of Michigan soils indicated that the maximum amount of phosphorus adsorbed per acre foot of soil ranged from 77 lb/acre foot for dune sand to 1898 lb/acre foot for Warsaw Clay Loam. The effect of soil horizon was found to be great, and the amount adsorbed in various horizons correlated well with the amount of iron or aluminum in the profile.[119]

Studies at Pennsylvania State University indicate that the orthophosphate anions bond chemically with surfaces of iron and aluminum oxyhydroxides and will form precipitates with iron and aluminum when they are in solution. The most weakly bonded phosphates readily equilibrate with the soil solution and would be considered available to plants. Phosphorus will penetrate to greater depths in some sandy soils due both to the greater hydraulic conductivity allowing less reaction time between the soil solution and the particle surfaces and the tendency of sandy soils to have lower iron, aluminum, and clay content.[120] Soil profile analysis is important to site selection for long-term phosphorus adsorption.

Surface runoff containing high phosphate concentrations must be controlled. The crop must, of course, be removed from the site to remove that portion of the phosphate which is taken up by crops from the system. A well managed system on properly selected soils would probably have no phosphorus pollution problems.

Trace Elements and Toxic Chemicals.

The effects of trace refactory organics are discussed in the section on organics. This section will be concerned with the nutrient and toxic effects of the trace inorganic chemicals in effluent wastewater. As mentioned earlier, one of the most effective methods of preventing problems with toxic levels of trace elements in land treatment is to impose pretreatment requirements on the source industries. Significant quantities of trace elements can also come from domestic sources. Examples are copper and zinc from copper and brass plumbing fixtures and heavy metals from urban runoff. Some elements such as heavy metals receive significant removal in secondary treatment and appear in the sludge rather than in the effluent.

Heavy metal effects on living organisms are presently being researched, especially as they relate to land disposal of sludge, but little is yet known. Most heavy metals are retained in the surface soil horizon by chelation by organic material, adsorption on colloidal clay material, and precipitation as insoluble oxides, hydroxides, phosphates, or sulfides.[121] The availability and toxicity of heavy metals in soil solution is a function of trace metal concentration, soil pH, soil organic content, presence and relative concentration of other metal ions, and crop type.

Most crops require far less trace elements or heavy metals than is applied in effluents. The result is a build-up of these elements in the soil. Both short-term acute effects and long-term chronic effects must be considered. There are presently available no reliable correlations between soil concentration levels and crop toxicity, no information on upper permissible levels in plants, and little is known about foliar adsorption during spraying.[122] Information on differences in accumulation of toxic metals in edible portions of crops grown on sites using sludge or effluent are almost non-existent. Almost nothing is known about toxic metal interactions (synergistic toxicity) or the effects of PO_4 interactions to alleviate toxicity and prevent plant transport of these toxic elements.[123] A survey of the available literature on the subject

(References 124-128) of trace elements or heavy metals indicates the following:

Arsenic. Little is known. It appears to be fairly immobile at normal pH and not to accumulate in plants.

Aluminum. Little is known. Some reported toxicity at 1 ppm.

Barium. Barium normally causes no problems.

Beryllium. Animals and plants show toxicity, but little is known.

Boron. Borax and perborates are being increasingly used in low or no-phosphate detergents, therefore, boron is of increased concern. Most boron remains in the effluent and is toxic to boron-sensitive crops at 0.75 ppm. Water containing more than 4 ppm is considered unsatisfactory for all crops. Corn shows toxicity at 1-2 ppm and alfalfa at 2-4 ppm. Boron will kill plants at levels below food chain hazard levels thereby interrupting the food chain path.

Cadmium. Cadmium is toxic in the food chain at levels below plant toxicity and plant accumulation is of concern. Little or no information is available on the movement of cadmium from feed grains or pasture into beef. The

Food and Drug Administration has not published acceptable levels but is initiating studies.

Chromium. Crop toxicity levels start at 4 to 5 ppm. Chromium appears to be non-injurious because it is rapidly reduced to Cr^{+3} in the soil and as such is immobile.

Cobalt. Field occurrences of cobalt toxicity are rare. Cobalt will kill plants before becoming a food chain hazard.

Copper. Copper is a plant micronutrient, but at higher levels represents a significant potential hazard to the food chain through accumulation in plants. Copper will cause severe plant injury before content is high enough to be toxic to most animals. Sheep are an exception. Some plants show toxicity at 0.1 ppm.

Cyanide. Cyanide is a trace organic about which little is known in this context.

Fluoride. Fluoride has little effect on plants and is toxic mainly to man and animals at high levels. Note in Table I that fluoride leaching to groundwater may reach significant levels.

Iron. Iron is relatively immobile in soil and should present no problems.

Lead. Lead is not a problem due to its reaction with phosphates in the soil, and is relatively insoluble in soils except for acidic, low phosphate soils.

Manganese. Manganese is relatively insoluble in soil.

Mercury. Mercury presents no problems for plants and the Food and Drug Administration has found no cycle into meat or milk from land treatment.

Molybdenum. Molybdenum normally occurs in low levels in most effluents. Denver effluent (Table I) is one of the unique effluents that could have potential problems. Molybdenum can accumulate in pasture forages at levels toxic to ruminant animals with no apparent plant toxicity, especially in calcareous soils or low pH. Intensive studies on molybdenum are in progress at the University of Colorado and Colorado State University.

Nickel. Nickel is mobile in soil only at low pH. It kills plants at levels below those considered to be food chain hazards.

Selenium. Selenium will collect in certain pasture plants at levels toxic to animals without apparent plant toxicity and care must be exercised to exclude these plants from forage crops or pasture.

Silver, Tin, Tungsten, Vanadium. Little is known, but there have been no reported toxicity problems.

Zinc. Some toxicity to animals through zinc concentration in plants has been observed, but most plants will show damage before reaching such levels. Available information on toxicity to animals from zinc in food crops is insufficient to establish a safe plant zinc level. Soil phosphates reduce zinc availability to plants.

Pathogens.

Present methods of disinfection of wastewaters are not uniformly effective against all potential wastewater pathogens. Viruses in particular may survive usual chlorination procedures. Standard methods for sample concentrations, isolation and culturing of viruses are not yet available. These factors plus virus mobility and survival in the soil are the primary concerns in the health aspects of land disposal.

Studies have shown that pathogenic bacteria are largely retained at or near the soil surface and that movement through the soil is not considered a problem except in the presence of high hydraulic loads, soils with high permeability, or shallow soils with faulted or fractured bedrock. The studies also indicated that pathogenic and indicator bacteria are eliminated from the soil rather rapidly by exposure to natural ultraviolet light, oxidation, desiccation, and antagonistic soil organisms.[129]

Research has shown that the fate of viruses is not necessarily the same as for bacteria; that they are found in wastewater samples which have had successful bacteria kills; and that they may be more mobile than bacteria in the soil due to their smaller size. Indicative of the state of the art on viruses is the fact that the infectious hepatitis virus has just recently been isolated.[130] Dispersion of viruses in spray aerosols is also little understood. Little is known about the health effects on livestock or on humans consuming livestock products from land treatment sites. Surface runoff from land treatment sites should be controlled to prevent contamination of adjacent areas. Underdrain water should be tested for pathogens since the use of underdrains reduces the effective filtering distance for viruses.

The literature contains little information on irrigation-caused disease transmission, which can indicate either the lack of a serious problem or a lack of adequate isolation and reporting. That a viral problem does exist is indicated by the fact that 540,000 Americans are afflicted each year with infectious hepatitis,[131] a virus that can be transmitted through contaminated drinking water.

More than 100 kinds of viruses are known to be excreted by man and approximately 70 of these have been found in sewage. Those that appear to be transmitted through wastewater are enteroviruses, poliomyelitis, coxsackie, and infectious hepatitis. The fragmented knowledge of the fate of such viruses as indicated by various researchers will be briefly discussed in the following paragraphs.

Reported average concentrations of viruses in raw wastewater range from 5 viruses per liter to 100,000 viruses per liter.[132] Identification of viruses in wastewater has been hampered by the limitations of sampling techniques, problems of concentration of samples, the complexity and high cost of laboratory procedures, and the limited number of facilities having the personnel and equipment necessary to perform the analytic service. Lund [133] reports that very little is known about the reactions which take place in rendering viruses innocuous. Various inactivation processes are discussed: spontaneous, thermal, chemical, and oxidative. There is a problem as to what part of the virus particles are affected, i.e. the nucleic acid and/or the proteins. If only the protein is affected, the nucleic acid is still potentially infectious.

Kruse, et al.,[134] have demonstrated that in the presence of ammonia, amino acids or other nitrogen compounds a zero coliform reading does not necessarily mean a virus kill.

Bacteria are commonly used as an indicator of virus movement in the soil. Bacteria sizes range from 0.3 micron to 50 micron with common bacteria being in the range of 0.5 micron to 3.0 micron.[135] Krone[136] reports that viruses range from about 0.01 microns for infectious hepatitis and polio viruses to 0.45 microns for psittacosis. The use of bacteria filtration in the soil as an indicator of virus removal is, therefore, open to question. Krone reports that some laboratory studies conducted on movement of viruses through granular media show that coagulation is important to removal of viruses, but even then only 90 percent removal was achieved by rapid sand filtration. It was also found that removal was greater at low flow rates. Krone also discusses the filtration processes in soil such as straining, bridging, and sedimentation. He concludes that until there is a simple way of describing the condition of the soil, the filtration relationships cannot easily be used to calculate numbers of organisms passing through a soil.

Eliassen[137] found that the removal of virus from percolating water is largely due to adsorption on the soil particles. Soils with clay content over 5 percent showed high adsorption of viruses. The equilibrium constant was also found to be sensitive to the pH and cation concentration. As the pH increased above 7, the fraction of viruses adsorbed decreased markedly due to the increasing negative charge on both the viruses and the soil particles causing mutual repulsion. For example, in a soil with 50 percent sand, 30 percent silt, and 20 percent clay, the adsorption was reduced by almost 40 percent when the pH was increased from 6.8 to 8.0. As the cation concentration in the water increased the fraction of virus adsorbed increased.

Krone concludes that there is no adequate theory for describing the movement of viruses through soil, but that the knowledge that adsorption is the important removal mechanism provides a qualitative description. Prolonged application of high concentrations of viruses to even clayey soils can eventually result in breakthrough of organisms. Very little information is available on unsaturated flow.

Romero[138] surveyed the literature on studies to determine the movement of bacteria and viruses through porous media such as soils. He concluded that studies concerning the travel of viruses during percolation indicated that some behave like bacteria while others, because of resistance to the environment, may travel greater distances than do bacteria.

Sorber[139] defines aerosols as particles in the size range of 0.01 to 50 microns which are suspended in the air. He indicates that specific studies of biological aerosols emitted by spray irrigation of wastewater have not been found in the literature.

There are very few, if any, public health problems that have been demonstrated as a result of spray irrigation or land disposal of wastewater. However, a significant number of questions have been raised, and research is needed before conclusions as to the existence of a hazard can be made.

California, as a state with significant wastewater reclamation, appears determined to avoid the risk in the interim. In California, wastewater must have a coliform MPN of 23/100 ml for spray irrigation of golf courses, parks, public access landscaped areas, landscape impoundments, and for spray irrigation of crops that will be processed before consumption. Wastewater must have a coliform MPN of 2.2/100 ml for use in recreational impoundments and for spray irrigation of produce that is eaten raw.[140]

Wildlife and Insects.

Considerable emphasis is developing regarding the effect of wastewater land disposal on the changes in both the population and the disease incidents amongst wild animals, birds, and mosquitos occupying the treatment site. Some work, notably at Pennsylvania State University, has been directed towards these areas. Additional areas needing research include the fate of protozoan parasites, the passive spread of microorganisms or infection by flying insects, and migrating birds and wildlife.[141]

Research at Pennsylvania State University indicated no major population changes in birds and mammals after 2 years. Increased mosquito populations were attributed to standing water on the site.[142] Studies of the effects on deer and rabbits are in progress.[143]

Standing water on sites can be avoided through management practices and proper site selection. Insect propagation in lagoons can be controlled through insecticides or possibly the use of Gambusia fish. The geology of the site selected will be important in regard to avoiding potential reappearance of groundwater in the form of swamps or ponds with their associated potential for insect and other problems.

Forage Animals.

Very little is known about the health effects on livestock or on humans consuming livestock pastured on or fed crops from land treatment sites. The hazards are site specific in that they relate to the effluent constituents, soil type, crop type, animal species and quality of management of the system.

Management tools available to reduce parasite and pathogen transmission opportunity through livestock include not allowing animals to graze the site, and allowing forage crops adequate curing time before harvesting. Elevated temperatures during fermentation of ensilage should be beneficial to die-off of pathogens.

Toxicity due to effluent residue on plants or to accumulation of trace elements in the forage will be site specific. Elements presently of concern that do not kill the forage before reaching levels toxic to animals are arsenic, beryllium, cadmium, copper, cyanide, fluoride, molybdenum, and selenium. Crop sample analysis should be performed routinely.

Nutritional analysis of the forage should be performed to be sure that animals being fed forage from land treatment sites are receiving properly balanced feed. The feed supplements required may differ from normal practice since forages from land treatment sites may not be similar to forages grown under normal irrigation. Protein level, calcium-phosphorus ratio, magnesium, potassium, cobalt, iodine, and molybdenum-copper ratio would be expected to be most critical.[144]

Crop Selection.

Crop selection is also site specific. Crops should be selected on the basis of minimizing the total system cost including capital costs and operating and maintenance costs. The climate requirements and growing season of the crop selected will affect the size of the winter storage reservoir. The nutrient uptake of the crop, the nutrient requirement profile, the ability of the crop to withstand wet feet, and the required harvest drying time will affect the amount of land required. The wastewater nutrient content is fairly uniform throughout the year, but crop nutrient demands vary as to crop type and season. Perennial grasses have fairly uniform nutrient requirements during the growing season, whereas the nutrient requirements of corn are more variable. This can lead to either increased storage requirements, or nutrient build-ups in the soil that may leach.

Efficient nitrogen removal requires total removal of the crop. For example, picking ear corn removes very little nitrogen. Having cattle subsequently graze the stalks removes only the amount of nitrogen that is converted into beef; the rest is recycled to the soil as manure.

Infiltration rate is affected both by the root density of the crop and the amount of soil compaction prevented by foliage coverage. Sodium, chloride, and trace element uptake or toxicity to the selected crop must also be considered. Erosion prevention and control are important factors. Shallow rooted crops will have less time to take up nutrients as the effluent passes through the root zone.

The APWA survey of land treatment facilities[145] indicated that for 82 municipal sites, 40% raised grass and 42% raised crops. For the 22 industries surveyed, 73% raised grass and 14% raised crops. The percent of total irrigated acreage breakdown for crops showed corn--30%, alfalfa--23%, and wheat--17%. The preference for perennial grasses is based on their higher ratings in almost all the selection factors mentioned earlier.

Comparison of the 1963-1970 crop yields for corn, corn silage, and alfalfa at the Pennsylvania State University fertilized control plots and the land treatment sites shows no significant differences in yields in years of normal precipitation, but quite significant differences in below normal years.[146] This indicates that in selecting a crop for a land treatment site, the average typical yields for fertilized, irrigated crops in the immediate area should be used; however, attention must be paid to the deleterious effects of over-irrigation if high hydraulic loadings are intended.

After obtaining typical yields for the site area, the optimization of crop selection becomes one of selecting the crop that minimizes the total system cost while providing the desired engineering features mentioned earlier. Care must be taken not to put too much emphasis on the apparent cash value of a crop such as corn, because it may be found that using reed canary grass could significantly reduce the size of the winter storage reservoir and the required treatment site acreage. These reduced annualized capital costs could more than compensate for the reduced value of the crop. Where hydraulic loading is the determining factor, reed canary grass is the better choice since it will withstand wetter conditions than corn without adverse effects. The higher nitrogen uptake rate and longer growing season for reed canary grass gives it a distinct advantage over corn. The discussion in the following paragraphs will deal with typical yields, crop nutrient uptake per acre, crop food value, analysis, and growing season for commonly selected crops.

Corn.

Corn grain crops are not normally used since removing only the ears does not remove a significant amount of nitrogen unless the stalks are also removed. Grazing the stalks allows significant amounts of their nitrogen content to remain on the site in the form of manure.

Yields of corn silage crops at Pennsylvania State University[147] (1965-1970) for the 2 inches/week sites averaged 5.6 tons/acre/year, with a range of 4.32 to 7.27 tons/acre/year. Average crop nitrogen uptake was 150 lbs/acre/year, with a range of 110 to 236 lbs/acre/year. Average phosphorus uptake was 35 lbs/acre/year. A typical corn silage nutrient analysis (1970) is shown in Table II.

The NO_3-N concentration below the corn site averaged 9.6 mg/l and twice exceeded the 10 mg/l limit. The NO_3-N concentration below the adjacent reed canary grass site averaged 3.0 mg/l for the same period and had a 3.6 mg/l maximum value.[148] Corn appears to be less efficient in protecting groundwater quality. Corn also has only a 3-4 month growing season during which significant nitrogen uptake occurs, and requires relatively dry conditions in the spring for planting and germination.

Alfalfa.

Alfalfa yields at Pennsylvania State University (1963-1967) averaged 4.8 tons/acre. Because alfalfa fixes significant nitrogen from the air, nitrogen uptake values were not available.[149] Because of this nitrogen fixation capability, care must be used when determining seasonal nitrogen requirements and application rates for alfalfa.

Reed Canary Grass.

Reed canary grass is a tall, cool season perennial with a rhizomatoue root system. It will grow in a very wet area, and can withstand flooding for over a month without permanent injury. It is one of the earliest grasses to begin spring growth, and is excellent for establishing a dense sod to control erosion. It may be difficult to get started due to low seed germination, but is almost indestructible once established.

Reed canary grass is becoming the most popular crop for land treatment sites due to the long growing season, the high nitrogen uptake, and the ability to withstand wet conditions. These characteristics can reduce the capital costs significantly by reducing the required land area and reservoir sizes compared to crops that do not have these characteristics.

Reed canary grass yields at Pennsylvania State University[150] (1965-1970) averaged 5.5 tons/acre/year with a range of 4.3 to 7.0 tons/acre/year. The 1973 reed canary crop yield at the Idaho Supreme Potato Plant at Furth, Idaho was 3.1 tons/acre/year.[151] Reed canary nitrogen uptake at Pennsylvania State University (1965-1970) averaged 355 lbs/acre/year or 97.3 percent of the applied amount.[152] The range was 272 to 408 lbs/acre/year.[153] Phosphorus uptake averaged 46 lbs/acre/year, or 35 percent of the applied amount. Combined soil and crop uptake of phosphorus totaled 99.2 percent of the applied amount.[154]

The total nitrogen uptake of reed canary grass at Idaho Supreme was 163 lbs/acre/year.[155] This is low compared to Pennsylvania State University and probably due to the fact that the Idaho Supreme effluent nitrogen is almost totally organic or significant denitrification may occur. Sites at Paris, Texas and Ames, Iowa report reed canary nitrogen uptakes of 361 and 400 lbs/acre/year, respectively. Missouri reports 359 lbs/acre/year nitrogen uptakes, 82 lbs/acre/year phosphorus uptakes and reed canary grass yields of 6.1 tons/acre/year.[156]

A typical nutrient analysis of reed canary grass at Pennsylvania State University (1970) is shown in Table II.[157]

TABLE II

CORN SILAGE AND REED CANARY GRASS NUTRIENT ANALYSIS

Nutrient	Average Nutrient Composition (%)		Total Amount Removed (lb/acre)	
	Reed Canary Grass	Corn	Reed Canary Grass	Corn
Nitrogen	3.69	1.34	408	161
Phosphorus	0.50	0.35	56	42
Potassium	2.23	1.07	247	128
Calcium	0.40	0.23	44	28
Magnesium	0.36	0.19	40	23
Chloride	1.57	0.39	158	47
Sodium (μg/g)	309	201	3.4	2.4
Boron (μg/g)	8	7	0.09	0.08

Reed canary grass can be made into hay or chopped for silage, but should be harvested before it becomes coarse and stemmy. Pennsylvania State University reports no change in digestible dry matter or protein was found from irrigation with effluent. All the sites growing reed canary grass found it to be an excellent livestock feed.

Monitoring.

Monitoring requirements are site specific due to the variation in site sizes and site characteristics. The APWA survey[158] found that "monitoring of land application facilities has been minimal and mostly inadequate. Many states appear not to have taken an active role in requiring use of monitoring facilities, apparently because there was no discharge to receiving waters. Industrial systems were generally better monitored, but control cannot be characterized as adequate in most cases".

The APWA survey also found that few tests were performed on system effluents or groundwater discharges. Of the 69 municipal systems, half indicated a lack of public health restrictions. The industrial systems reported that 80 percent operated without public health restrictions. Monitoring of groundwater, surface water sources, soils, crops, animals and insects is practiced in some locations and minimally used in others, often dependent solely on the requirements of public health authorities.

Factors that need to be considered for monitoring are groundwater, soil, crops, underdrain effluent, lagoon leakage, and adjacent surface waters. Adequate background data for any of these parameters is mandatory before initiating operation. The background data serves as a data base from which to judge systems performance.

Some monitoring techniques such as for viruses and trace elements in soils are just being developed.[159] Other techniques such as soil testing, plant analysis and groundwater testing are well developed and should be required. Plant and soils analysis are available at most state agricultural research stations, extension services, or universities. Groundwater testing can be done in conjunction with effluent testing. Pressure-vacuum lysimeters represent the single best approach to sampling soil water. They are inexpensive, easy to install, and can be used at depths from 6 inches to 60 feet.[160]

The number, location and depth of groundwater sampling wells will be site specific. Consideration must be given to the fact that a groundwater mound beneath the site will change the groundwater depth and flow direction characteristics. Consideration also should be given to the fact that polluted percolate water will stratify on top of the water table. The Michigan Department of National Resources has had considerable experience in this area in developing the monitoring program for the Muskegon County project.[161]

Answers to land treatment efficiency and monitoring requirements are being sought by the EPA through projects such as those at Muskegon, Michigan and Pennsylvania State University. The Muskegon project will be monitored for 5 years through an EPA grant of over $2 million. Complementary studies are to be undertaken by the University of Michigan, Michigan State University, and the Michigan Department of Natural Resources under a separate EPA grant.[162]

CHAPTER V

REGION VIII SURVEY RESULTS

A survey of the use of land application of wastewater effluents was conducted encompassing the Rocky Mountain Prairie Region of the EPA, Region VIII, which includes the States of Colorado, Montana, North Dakota, South Dakota, Utah and Wyoming. Of prime interest were those sites utilizing spray irrigation, overland flow or ridge and furrow irrigation which had preplanned or intentional direct uses of effluents. Not included are sites such as lagoons with emergency outfalls to land, or discharges to streams or return flow irrigation ditches where dilution or ultimate destination of the effluent is unknown. If discharges to streams or irrigation ditches with possible reuse downstream were to be considered land treatment, almost every discharge in Region VIII would be included. The land treatment sites included in the survey are those sites where full control is maintained over the effluent for at least a portion of the year. Even then, most responses indicated that the user's intent was predominantly reuse as low cost irrigation water, rather than concern for advanced waste treatment or the environment. Individually owned and operated domestic aerobic "package" treatment systems also were not included.

The list of sites to be surveyed was developed through review of known listings such as the 1968 Inventory of Municipal waste Facilities by the EPA, EPA files on federal installations, and inquiries to engineers of the U.S. Forest Service, various engineering firms and the state water pollution control engineers of the states within the region. All sites of possible land application of secondary effluents were first investigated by means of telephone inquiries to complete survey questionnaires. This assured obtaining at least some data for all sites without extensive travel. It also avoided the poor response to mail surveys, and allowed direct inquiry into the unique aspects of each site as they were discussed with the persons being surveyed.

The survey questionnaire (Reference Appendix A) centered around the main topics of (a) general considerations, (b) legal aspects, and (c) engineering systems. The queries included: flow and storage, pretreatment, significant effluent water characteristics, soil, geological and topographical characteristics of the site, irrigation methods used, crop or land use, environmental monitoring of the site, and capital and operating and maintenance costs.

Six industrial and thirty-seven municipal sites met the definition of land treatment. Thirty-one of these sites are either operating or installed. The significant survey data for these sites appears in Appendix B. Twelve of the sites are in the study or plans and specification stage of development. A short description of these sites appears in Appendix C. Major sites that have appeared in other surveys that were found not to meet the true definition of land treatment, and are therefore not included, were: Cheyenne, Wyoming; Rawlins, Wyoming; Helena, Montana; Tooele, Utah; and West Yellowstone, Montana.

General Site Data

The state location of known sites categorized as operating, under construction, planned or seriously being considered for the near future are indicated in Table III. The year each site was placed, or planned to be, in service is given in Table IV. A breakdown of land use of existing sites is given in Table V.

TABLE III

REGION VIII SITES

State	Operating	Under Construction	Plans & Specs	Serious Consideration
Colorado	10	6	4	3
Montana	2	2	1	2
North Dakota	1	-	-	1
South Dakota	1	-	-	-
Utah	4	2	-	-
Wyoming	1	2	-	1
TOTAL	19	12	5	7

TABLE IV

YEAR SITES PLACED IN SERVICE

Date	Number of Sites	Date	Number of Sites
1951	1	1970	2
1958	1	1971	1
1959	1	1972	2
1960	1	1973	6
1964	2	1974	11
1967	1	Proposed	12
1969	2		

TABLE V

DISTRIBUTION OF EXISTING SITES BY LAND USE

Golf	14	Natural Vegetation	6
Crops		Landscaping	3
Hay & Grass	5	Pasture	3
Alfalfa	2	Forest	1
		Undecided	1

The predominant reasons given for choosing land application of secondary effluents for existing and proposed sites were:

TABLE VI

LAND DISPOSAL REASON

Reason	Number
Water already owned by user and available for secondary use such as golf course irrigation	18
Avoid direct discharge to stream	15
Lower cost of treatment on seasonal waste	4
No stream available for discharge	2
Offensive odors if lagooned	2
Only to maintain water rights	1
Overloaded lagoon	1

The predominant use of land application of effluents in Region VIII is municipal or private golf

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courses along the Front Range of Colorado, where the effluent was already owned by the user and was a low or no-cost irrigation water source. Eighty-seven percent of the 31 existing sites are less than 10 years old, fifty-five percent are less than 2 years old, and fifty-two percent are in Colorado. Golf courses constitute forty-five percent of the site uses. Forty-two percent of the sites chose to use the effluent as irrigation water, whereas thirty-five percent indicated new state or federal stream standards were the main reason for using or proposing land disposal of effluents. No attempt was made to determine if the emphasis was on disposal or on treatment. The lack of site monitoring indicates disposal probably is the major intent. A major determinant appeared to be the lack of standards on land disposal as compared to increasingly stringent stream disposal standards.

No water rights adjudications or legal oppositions have been encountered by the existing sites. The primary reasons for this are believed to be: (1) the water was initially purchased from a municipality or is owned and therefore can be totally consumed or reused; (2) the water originates from transbasin diversion; (3) dominion has been maintained on the effluent water; (4) the water is deep well water; and (5) the water right is a federal reserve right.

Fourteen of the 31 sites are new and have had no operating experience. Five of the remaining 17 sites indicate some odor problems have been encountered. This arises primarily from anaerobic conditions or algae growths in storage ponds (water hazards) on golf courses, or a too long detention time on food processing effluents. Many of the golf courses have adjacent housing, and they indicate that public acceptance in general has been good. Some golf courses concede that spraying at night helps maintain a low profile and that the neighbors may not know the source of the water. Odor conditions are usually related to anaerobic pond conditions caused by overloaded conditions on the primary and secondary treatment systems. The algae problems have also caused some user complaints about plugged sprinkler heads, even in cases where filters were in use.

Systems Descriptions

The types of pretreatment received by the effluents before application at the existing sites are given in Table VII.

TABLE VII

EFFLUENT PRETREATMENT

Number of Sites	Pretreatment
6	Activated sludge with chlorination and polishing pond.
1	Activated sludge with no chlorination
1	Activated sludge with tertiary treatment and chlorination
4	Extended aeration with chlorination and polishing pond
1	Two cell aerated lagoon
5	Two cell aerated lagoon with chlorination
3	Two cell aerated lagoon with chlorination and polishing pond
1	Anaerobic lagoon with polishing pond
3	Trickling filter with chlorination and polishing pond
1	Trickling filter with chlorination
4	Screening only (industrial)
1	Septic tank with chlorination

The average daily flow of the sites presently in operation was 0.75 MGD per site with a range from 8000 GPD to 3.0 MGD. The average design flow for the existing and proposed plants surveyed was 0.75 MGD with a range from 40,000 GPD to 3.6 MGD. Only 6 of the 31 existing sites had design flows greater than 1.0 MGD. These values are comparable to statistics for California where 110 waste treatment facilities whose effluents are used for crop or landscape irrigation have an average flow rate of 0.79 MGD per facility with a range from 40,000 GPD to 14 MGD.[163]

Eight of the existing sites were presently discharging to streams during the winter months. Seven sites were new housing developments with present populations sufficiently small to have totally contained land treatment sites. Eight sites were lagoon systems with enough storage capacity to be totally contained in winter. Two sites were seasonal and had no winter flow. Five industrial sites continued irrigation through the winter months.

The significant industrial effluent constituents reported were whey by-products in the three cheese factory effluents and high BOD and suspended solids in the three food processing plants. The BOD of effluents being successfully used in Region VIII ranged from less than 5 mg/l to 1600 mg/l. The suspended solids range was from less than 5 mg/l to 500 mg/l.

The average area of existing sites by use in Region VIII where effluent is used for irrigation is given in Table VIII. Soil types for existing sites ranged from sandy to clayey to unknown types with the distribution shown in Table IX. Adjacent land use for the existing sites are given in Table X.

TABLE VIII

AVERAGE ACREAGE BY USE

Number of Sites	Use	Average Area
14	Golf	112 acres
11	Crop/Pasture	60 acres
3	Landscape/Recreational	82 acres
6	Natural Vegetation	6 acres
1	Forest	8 acres

TABLE IX

SOIL TYPES

Soil Type	Number of Sites
Sandy loam	11
Sandy	6
Loam	1
Clay loam	1
Silty clay	1
Silty loam	1
Unknown	10

TABLE X

ADJACENT LAND USE

Use	Number of Sites
Farming	13
Housing	10
Forest	5
Open area	3

Irrigation equipment utilized was almost exclusively of the below ground, solid set, impact sprinkler type as noted below:

TABLE XI

IRRIGATION EQUIPMENT

Irrigation Equipment	Number of Sites
Solid set (below ground)	21
Solid set (above ground)	4
Portable	3
Movable boom	2
Overland flow	2

Irrigation rates presently being used were quite variable. Eight sites, which were predominantly golf courses, irrigate on an "as required" basis. For those sites where a known quantity of water was being applied each week, the range of effluent application was from 0.6 inches per week to 3.5 inches per week with an average of 1.7 inches per week.

The irrigation season was dependent upon the growing season except for the year around operations. The five industrial sites which utilize winter disposal applications reported no adverse effects upon the ground covers due to winter spraying. Golf courses reported the start of green-up spraying as early as March and continuation of spraying through October.

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Overland flow	2

Irrigation rates presently being used were quite variable. Eight sites, which were predominantly golf courses, irrigate on an "as required" basis. For those sites where a known quantity of water was being applied each week, the range of effluent application was from 0.6 inches per week to 3.5 inches per week with an average of 1.7 inches per week.

The irrigation season was dependent upon the growing season except for the year around operations. The five industrial sites which utilize winter disposal applications reported no adverse effects upon the ground covers due to winter spraying. Golf courses reported the start of green-up spraying as early as March and continuation of spraying through October.

The availability of capital cost and operating and maintenance cost data varied from minimal to non-existent, thereby preventing a meaningful determination of typical costs.

Monitoring

Observed during the survey was a widespread lack of awareness of the pollution potential from the use of effluents for irrigation, coupled with a comparable lack of state guidelines or requirements on design discharges or monitoring. The sites are typically designed so that percolation to groundwater occurs, yet none of the states in Region VIII have promulgated standards for groundwater quality nor established specific requirements or a permit system for discharges to groundwater. The State of Montana has required some monitoring of sites adjacent to no-degradation streams but the monitoring requirements are far from comprehensive. Federal agencies such as the U.S. Forest Service and the National Park Service have been including monitoring capabilities for parameters such as groundwater quality in the design for land application sites within the Region, primarily at the insistence of EPA and other agency officials. Some site monitoring is performed at industrial sites primarily because of the nature of their effluents.

Most golf course sites do not monitor. The potential health hazards to a golfer wading through water hazards containing effluent with fecal coliform MPN counts of 5000/100 ml or higher is totally ignored, as are aerosol drift prevention, drift control, and monitoring. Pollution of surface waters from runoff from land disposal sites is uncontrolled and unmonitored at all but a few sites.

The general lack of availability of information on basic engineering prerequisites such as site geology, subsoils, soil depth, or water table depth indicates that these factors probably weren't even considered in site design. This would be expected where the primary purpose involved is effluent use as irrigation water or effluent disposal rather than advanced treatment. The few sites that had monitoring requirements also had considered these basic design prerequisites, thereby demonstrating a better understanding of the environmental impact of land treatment.

Conclusions

Land application of effluents is presently used at 31 sites within Region VIII. These sites are best typified as land disposal sites rather than land treatment sites, since very few showed concern for the treatment aspect of application of effluents to the land. The amount of engineering going into all but a few sites was limited and typically required no more technical ability than that needed to lay out a golf course or irrigation system. Secondary environmental effects were only considered when and where a state or federal agency required it. The site monitoring data indicates that twenty-two of thirty-one sites are totally without monitors of any kind.

The need for the states within Region VIII to take the lead in promulgating standards and requirements for land disposal of wastewater effluents is evident. Including sites for land disposal of effluent in a discharge permit system can provide a mechanism for review of site design and operation by state water pollution control engineers. Monitoring, sampling, and reporting requirements will help ensure that sites are properly operated and maintained.

Design guidelines need not be detailed or try to address the multiplicity of site specific variables that may be encountered. The tendency of detailed guidelines to become design standards must be avoided. Poor design has resulted from the arbitrary selection of the 2 inches/week application rate used at the Pennsylvania State University site. Increasing incidence of land disposal is noticeable in the data as the states adopt more stringent stream standards.

Prevention of stream pollution is no virtue if it results in air, land, or groundwater pollution.

Lack of adequate design, monitoring and effective management can result in lawsuits similar to that which involved the City of Hobbs, New Mexico, or result in situations like Lubbock, Texas and Fresno, California which have nitrate groundwater pollution problems at their land disposal sites. Because groundwater pollution from land disposal of effluents is much less transitory than stream pollution, the need is to design and manage the system so that groundwater pollution does not occur.

Recommendations

The proper design of a facility for the land application of effluents is site specific. Therefore, state standards and requirements must be flexible to allow the designer the latitude required for proper design. Some points for consideration in the development of standards or requirements, based on the survey, are:

1. Proper effluent application rates are site specific as to soil type, topography and annual precipitation.
2. Many industrial effluents such as food processing wastes are best handled while they are

fresh. Inflexible mandatory pretreatment standards such as a minimum of secondary treatment with chlorination may be self defeating in some cases.

3. The goal of zero discharge to surface waters should not give freedom to pollute groundwaters. Up-gradient and down-gradient wells to monitor groundwater quality are mandatory. Groundwater monitoring is not necessarily more complex than the effluent monitoring already being done.
4. Annual soil sample analysis can be useful in heading off soil toxicity problems such as a build-up of salts.
5. Design review and approval by a team consisting of a qualified soils engineer, a hydrologist, a geologist and an agronomist should be required to insure proper design.
6. Design feasibility approval by the state water engineer would avoid many potential water rights conflicts.
7. Total analysis of the wastewater effluent being considered for land disposal is mandatory to identify potential toxic and trace element problems before design is initiated.
8. Insect abatement requirements (such as mosquitos) need to be addressed as to both nuisance

effects and disease vector potential. Aerosol drift must also be considered.

9. Land disposal requirements need to be updated continuously to include new developments in the areas of viruses and toxic element control and monitoring.
10. Use of water hazards on golf courses as storage for secondary effluents with high fecal coliform counts should be carefully reviewed by the regulatory state agencies.
11. Chlorination requirements for effluent uses on golf courses or other recreational sites should be reviewed in comparison to the California requirements and the present knowledge of virus pathogen survivability.
12. It is the demonstrated intent of the EPA to bring groundwater pollution under control by 1983. Design engineers therefore need to know the state requirements for land treatment design that reflect this deadline.

It should be noted that all requests for Federal moneys for construction after June 30, 1974 will have to consider land treatment as an alternative method of wastewater treatment in the cost effective analysis per Public Law 92-500. What is to be considered at the state level in such an analysis is presently undefined due to the lack of state control or state requirements. Also, the preliminary EPA definition of "best practical treatment" for municipal effluents clearly indicates the intent to bring groundwater pollution under control by 1983. Wastewater treatment facilities to meet those requirements are being designed now. The need for state requirements and regulations of land treatment is immediate. Initiation of state rules and regulations cannot wait until after the current state effort on stream quality standards is complete.

BIBLIOGRAPHY

1. Pound, Charles E. and Ronald W. Crites. *Wastewater Treatment and Reuse by Land Application*, Volume II, Environmental Protection Agency, Washington D.C., Publication No. EPA-660/2-73-006b, August 1973. pp. 9-11.

2. TEMPO, General Electric Company--Center for Advanced Studies. *Polluted Groundwater: Some Causes, Effects, Controls, and Monitoring*, Environmental Protection Agency, Washington D.C., Publication No. EPA-600/4-73-001b, July 1973. pp. 1-11.

3. Sullivan, Ralph H. "Federal and State Legislative History and Provisions for Land Treatment of Municipal Wastewater Effluents and Sludges", *Proceedings of the Joint Conference on Recycling Municipal Sludges and Effluents on Land*, Champaign, Illinois, July 1973. p. 11.

4. Sullivan, pp. 13-17, 22.

5. Deaner, David G. *California Water Reclamation Sites--1971*, California State Department of Health, June 1971. p. i.

6. Deaner, pp. 19-36.

7. __________. *Water Reclamation*, California State Department of Public Health, 1972. p. 12.

8. __________. *Water Reclamation*, p. 13.

9. __________. *Water Reclamation*, p. 14.

10. __________. *Water Reclamation*, p. 71.

11. Bogedain, Frank O. "New York State's View of Land Disposal", *Proceedings of the Conference on Land Disposal of Municipal Effluents and Sludges*, Rutgers University, EPA Publication No. EPA-902/9-73-001, March 1973. pp. 153, 156.

12. Rhindress, Richard C. "Spray Irrigation--The Regulatory Agency View", *Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland*, Pennsylvania State University Press, 1973. p. 442.

13. United States Congress. Public Law 92-500, 92nd Congress, S. 2770, October 18, 1972, Laws of the United States Relating to Water Pollution Control and Environmental Quality, compiled by the Committee on Public Works, U.S. House of Representatives, March 1973. pp. 28, 29.

14. Sullivan, p. 5.

15. Public Law 92-500, p. 42.

16. Public Law 92-500, p. 7.

17. Public Law 92-500, p. 9.

18. Public Law 92-500, p. 20.

19. Public Law 92-500, p. 39

20. Public Law 92-500, p. 51.

21. Public Law 92-500, p. 99.

22. Environmental Protection Agency. "National Pollutant Discharge Elimination System", Federal Register, May 22, 1973. p. 13529.

23. Environmental Protection Agency. "Preparation of Environmental Impact Statements--Interim Regulations", Federal Register, January 17, 1973. p. 1698.

24. Environmental Protection Agency. "National Pollutant Discharge Elimination System", Federal Register, May 22, 1973. p. 13529.

25. Environmental Protection Agency. "National Pollutant Discharge Elimination System", Federal Register, May 22, 1973. p. 13530.

26. Environmental Protection Agency. "Cost-Effectiveness", Federal Register, July 3, 1973.

27. Environmental Protection Agency. "Pollutants in Publicly Owned Treatment Works", Federal Register, July 19, 1973. p. 19237.

28. Environmental Protection Agency. "Secondary Treatment Information", Federal Register, August 17, 1973. p. 22298.

29. Environmental Protection Agency. "Information on Alternative Waste Management Techniques and Systems to Achieve Best Practicable Waste Treatment", (Preliminary Copy dated 10-3-73). pp. 1-12.

30. American Public Works Association (APWA). *Survey of Facilities Using Land Application of Wastewater*, Draft Copy, April 1973. pp. 164-176.

31. Colorado Department of Health. *Criteria Used in the Review of Wastewater Treatment Facilities*, June 1973. p. 35.

32. Water Quality Control Commission. *Proposed Water Quality Standards for Colorado*, November 1973. pp. 1-58.

33. APWA, pp. 150, 154, 158.

34. Colorado Department of Health. "Rules, Regulations and Standards for Certain Domestic Sewage Treatment Systems and Other Non-Municipal Systems Other Than Septic Tanks", APWA *Survey of Facilities Using Land Application of Wastewater*. Draft Copy, April 1973. pp. 166-168.

35. Center for the Study of Federalism. *Green Land--Clean Streams*. Temple University, 1972. p. 237.

36. Legislative Assembly of the State of Montana. Senate Bill No. 444, Chapter No. 452, *Montana Sessions Laws of 1973*, March 1973. p. 1.

37. __________. *Proposed Montana Water Quality Standards*, 16-2.14(10)-S14480. April 11, 1973. p. 17.

38. APWA, p. 155.

39. Center for the Study of Federalism, p. 262.

40. State of North Dakota. *Standards of Surface Water Quality* (undated). pp. 1-17.

41. APWA, p. 156.

42. Center for the Study of Federalism, p. 272.

43. South Dakota Committee on Water Pollution. *Water Quality Standards for the Surface Waters of South Dakota*, February 16, 1967. pp. 1-59.

44. APWA, p. 156.

45. Center for the Study of Federalism, p. 279.

46. Utah State Division of Health. *Code of Waste Disposal Regulations*, May 1965. pp. I-6, II-8.

47. Center for the Study of Federalism, p. 284.

48. APWA, p. 156.

49. Wyoming Department of Health and Social Services. *Water Quality Standards for Wyoming*, June 28, 1973. pp. 1-10.

50. APWA, p. 157.

51. Center for the Study of Federalism, p. 293.

52. Office of Water Programs. *Subsurface Water Pollution, Part III*, Environmental Protection Agency, Washington D.C., March 1972. p. 206.

53. Postlewait, John C. and Harry J. Knudson. "Some Experiences in Land Acquisition for a Land Disposal System for Sewage Effluent", *Proceedings of the Joint Conference on Recycling Municipal Sludges and Effluents on Land.* Champaign, Illinois, July 1973. pp. 25-37.

54. __________. "Drought Threatens Trout in Montana", *Denver Post*, July 29, 1973.

55. Moses, Raphael J. "Legal Aspects of Land Treatment of Secondary Effluent", (Presented at the Symposium on Land Treatment of Secondary Effluent. University of Colorado. November 8, 1973.) pp. 1-12.

56. Farmers Highline Canal & Reservoir Company v. City of Golden, (1954) 129 C.575, 272 P. 2d 629, citing Baer Brothers Land & Cattle Co. v. Wilson, 38 Colo. 101, 88 P. 534, 107 P. 1108; City and County of Denver v. Colorado Lane & Livestock Co., 86 Colo. 191, 279 P. 46; Baker v. Pueblo, 87 Colo. 489, 491, 289 P. 603; Farmers Reservoir & Irrigation Co. v. Town of Lafayette, 93 Colo. 173, 24 P. 2d 756; Faden v. Hubbell, 93 Colo. 358, 369, 28 P. 2d 247; Del Norte Irrigation District v. Santa Maria Reservoir Co., 108 Colo. 1, 7, 113 P. 2d 676.

57. Farmers High Line & Reservoir Co. v. Wolf, 23 Colo. App. 570, 131 P. 291 (1913), and Mendenhall v. Lake Meredith Reservoir Co., (1953) 127 C. 444, 257 P. 2d 414. See also a case decided after the Golden case: Hallenbeck v. Granby Ditch & Reservoir Co., (1966) 420 P. 2d 419.

58. Vogel v. Minnesota Canal & Reservoir Co., *supra*, n.1; Farmers High Line & Reservoir Co. v. Wolf, *supra*, n.2.

59. 70 Colo. 565, 203 P. 681 (1922).

60. 499 P. 2d 1190 (1972).

61. 506 P. 2d 144 (1972).

62. 50 Colo. 606, 115 P. 705 (1911).

63. Mabee v. Platte Land Co., 17 Colo. App. 476, 68 P. 1058 (1902), the Fairplay Hydraulic Mining Co. v. Weston, 29 Colo. 158, 67 P. 160 (1901).

64. Denver Regional Council of Governments. *Water Quality Management Planning Program--Appendix B*. Preliminary Draft, November 20, 1973. pp. 28, 43.

65. APWA, pp. 2, 3.

66. Pound and Crites. "Wastewater Treatment ...", p. 62.

67. Rhindress, p. 452.

68. Chaiken, Eugene I., et al. "Muskegon Sprays Sewage Effluents on Land", Civil Engineering, ASCE. May 1973. pp. 49-53.

69. Barbolini, Robert R. "Institutional Options for Recycling Urban Sludges and Effluents on Land", *Proceedings of the Joint Conference on Recycling Municipal Sludges and Effluents on Land*. Champaign, Illinois, July 1973. p. 202.

70. Fuhriman, Dean K. and James R. Barton. *Groundwater Pollution in Arizona, California, Nevada and Utah*. Environmental Protection Agency, Washington D.C., Publication No. 16060 ERU, December 1971. p. 105.

71. Wells, Dan M. and Robert W. Sweazy. "Multiple Reuse of Municipal Wastewater in Lubbock", Texas Tech University, p. 9.

72. Wright, John R. Chief, Water Quality Section, Environmental Improvement Agency, Santa Fe, New Mexico. Personal Communication, October 4, 1973.

73. Jones, David C. An Investigation of the Nitrate Problem in Runnels County, Texas. Environmental Protection Agency, Washington D.C., Publication No. EPA R2-73-267, June 1973. p. 8.

74. Dunbar, John O. "Public Acceptance--Education and Informational Needs", Proceedings of the Joint Conference on Recycling Municipal Sludges and Effluents on Land. Champaign, Illinois, July 1973. pp. 208-210.

75. Postlewait, John C. and Harry J. Knudsen. "Some Experiences in Land Acquisition for a Land Disposal System for Sewage Effluent", Proceedings of the Joint Conference on Recycling Municipal Sludges and Effluents on Land. Champaign, Illinois, July 1973. pp. 25-38.

76. Schramm, Jack J. "Some Observations about the Legal and Political Implications of Applying Municipal Waste on Land", Proceedings of Conference on Disposing of Treated Municipal Effluent on the Land. University of Missouri at Columbia, March 20, 1973. pp. 57-66.

77. Brimberg, Judith. "Sewage-Sludge Plan Reservations Voiced", Denver Post, February 18, 1973.

78. Pound, Charles E. and Ronald W. Crites. Wastewater Treatment and Reuse by Land Application--Volume II. Environmental Protection Agency, Washington D.C., Publication No. EPA 660/2-73-0066, August 1973. pp. 141-158.

79. Pound, Charles E. and Ronald W. Crites. "Nationwide Experiences in Land Treatment", Proceedings of the Conference on Land Disposal of Municipal Effluents and Sludges. Rutgers University, March 1973. EPA Publication No. EPA 902/9-73-001. p. 240.

80. Environmental Protection Agency. "Preparation of Environmental Impact Statements--Interim Regulations", *Federal Register*, January 17, 1973. p. 1698.

81. Myers, Earl A. "Sprinkler Irrigation Systems: Design and Operation Criteria", *Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland*. Pennsylvania State University Press, 1973. p. 331.

82. Goddard, Maurice K. "Needed Directions in Land Disposal", *Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland*. Pennsylvania State University Press, 1973. p. 5.

83. Rhindress, p. 490.

84. Bogedain, p. 157.

85. Pound and Crites, "Wastewater Treatment ...", pp. 50, 52.

86. Pound and Crites, "Wastewater Treatment ...", p. 94.

87. Lindstedt, K.D., E.R. Bennett and S.W. Work. "Quality Considerations in Successive Water Use", JWPCF 43:8 (August 1971), pp. 1686, 1687.

88. National Technical Advisory Committee. *Water Quality Criteria*. FWPCA, Washington D.C., 1968. p. 20.

89. Environmental Protection Agency. "Information on Alternative Waste Management Techniques and Systems to Achieve Best Practicable Waste Treatment". (Preliminary Copy dated 10-3-73). pp. 7, 8.

90. National Technical Advisory Committee, p. 152.

91. Pound, Charles E. and Ronald W. Crites. "Characteristics of Municipal Effluent", *Proceedings of the Joint Conference on Recycling Municipal Sludges and Effluents on Land.* Champaign, Illinois, July 1973. p. 53.

92. Parizek, Richard R. "Site Selection Criteria for Wastewater Disposal--Soils and Hydrogeologic Considerations", *Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland*. Pennsylvania State University Press, 1973. p. 95.

93. Bureau of Water Quality Management. *Spray Irrigation Manual*. Pennsylvania Department of Environmental Resources, Publication No. 31, 1972. pp. 1-49.

94. Bureau of Water Quality Management (Pennsylvania), p. 9.

95. Pound and Crites. "Wastewater Treatment ...", p. 44.

96. Pound and Crites. "Wastewater Treatment ...", p. 40.

97. Bouwer, Herman. "Land Treatment of Liquid Waste: The Hydrologic System", Proceedings of the Joint Conference on Recycling Municipal Sludges and Effluents on Land. Champaign, Illinois, July 1973. p. 104, 105.

98. Pound and Crites. "Wastewater Treatment ...", p. 45.

99. Pound and Crites. "Wastewater Treatment ...", p. 34.

100. Parizek, p. 115.

101. Bureau of Water Quality Management (Pennsylvania), p. 10.

102. Bouwer, p. 104.

103. Skogerbee, Gaylord V. and James P. Law, Jr. *Research Needs for Irrigation Return Flow Quality Control*. Environmental Protection Agency, Washington D.C., Publication No. 13030, November 1971. pp. 25, 80.

104. Pound and Crites. "Wastewater Treatment ...", p. 22.

105. Pound and Crites. "Wastewater Treatment ...", p. 25.

106. Thomas, Richard E. "Fate of Materials Applied", Robert S. Kerr Environmental Research Lab. (Presented at the Conference on Land Disposal of Wastewaters. Michigan State University, East Lansing. December 6-7, 1972). p. 64.

107. Thomas, p. 65.

108. Ongerth, H.J., et al. "Public Health Aspects of Organics in Water", Journal AWWA (July 1973). pp. 495-498.

109. Miller, R.H. "The Soil as a Biological Filter", Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. Pennsylvania State University Press, 1973. pp. 75-76.

110. Ellis, Boyd G. "The Soil as a Chemical Filter", Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. Pennsylvania State University Press, 1973. p. 49.

111. National Technical Advisory Committee, pp. 164-167.

112. National Technical Advisory Committee, p. 170.

113. Sorber, Charles A. "Protection of the Public Health", Proceedings of the Conference on Land Disposal of Municipal Effluents and Sludges. Rutgers University, March 1973. EPA Publication No. EPA 902/9-73-001. p. 207.

114. National Technical Advisory Committee, p. 155.

115. National Technical Advisory Committee, p. 156.

116. Pound and Crites. "Wastewater Treatment ...", p. 26.

117. Bollag, Jean-Marc. Nitrate and Nitrite Volatilization by Microorganisms in Laboratory Experiments. Environmental Protection Agency, Washington D.C., Publication No. EPA 660/2-73-002, August 1973. p. 1.

118. Lance, J.C. "Nitrogen Removal by Soil Mechanisms", Journal WPCF, 44:7 (July 1972). p. 1360.

119. Ellis, p. 53.

120. Hook, J.E., L.T. Kardos and W.E. Sopper. "Effects of Land Disposal of Wastewaters on Soil Phosphorus Relations", *Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland*. Pennsylvania State University Press, 1973. p. 205.

121. Miller, p. 87.

122. Melsted, S.W. "Soil-Plant Relationships (Some Practical Considerations in Waste Management)", *Proceedings of the Joint Conference on Recycling Municipal Sludges and Effluents on Land*. Champaign, Illinois, July 1973. pp. 125-126.

123. Chaney, Rufus L. "Crop and Food Chain Effects of Toxic Elements in Sludges and Effluents", *Proceedings of the Joint Conference on Recycling Municipal Sludges and Effluents on Land*. Champaign, Illinois, July 1973. pp. 129,138.

124. National Technical Advisory Committee, pp. 151-155, 163.

125. Chaney, pp. 129-140.

126. University of Missouri Extension Division. *A Guide to Planning and Designing Effluent Irrigation Disposal Systems in Missouri*, Publication MP 337, March 1973. pp. 19, 76-81.

127. Lindsay, W.L. "Inorganic Reactions of Sewage Wastes with Soils", *Proceedings of the Joint Conference on Recycling Municipal Sludges and Effluents on Land*. Champaign, Illinois, July 1973. pp. 91-96.

128. Jelink, Charles. "Informal Opinions", HEW, Food and Drug Administration. *The Joint Conference on Recycling Municipal Sludges and Effluents on Land*. Champaign, Illinois, July 1973. pp. 215-216.

129. Miller, pp. 85-86.

130. __________. "Hepatitis-Causing Particle Isolated", *Denver Post*, November 30, 1973.

131. __________. "Hepatitis-Causing Particle Isolated", *Denver Post*, November 30, 1973.

132. Foster, D.H. and R.S. Engelbrecht. "Microbial Hazards in Disposing of Wastewater on Soil", *Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland*. Pennsylvania State University Press, 1973. p. 253.

133. Lund, Ebba. "Inactivation of Viruses", Sixth International Water Pollution Research, Session 14, Paper 28, June 1972. pp. 1-3.

134. Kruse, C., et al. "Halogen Action on Bacteria, Viruses and Protozoa", *Proceedings of the National Specialty Conference on Disinfection*, University of Massachusetts, Amerhurst, Mass., July 1970.

135. McKinney, Ross E. Microbiology for Sanitary Engineers. New York: McGraw Hill Book Co., Inc., 1962. p. 29.

136. Krone, R.B. "The Movement of Disease Producing Organisms Through Soils", *Municipal Sewage Effluent for Irrigation*, Ruston, La., Louisiana Tech Alumni Foundation, 1968. pp. 75-105.

137. Eliassen, R., et al. "Studies on the Movement of Viruses with Groundwater", Water Quality Control Research Lab., Stanford University, 1967.

138. Romero, J.C. "The Movement of Bacteria and Viruses Through Porous Media", *Journal of Groundwater*, 8:37.

139. Sorber, p. 205.

140. __________. Water Reclamation, pp. 71-72.

141. Sorber, p. 205-206.

142. Parizek, R.R., et al. "Wastewater Renovation and Conservation", *Pennsylvania State University Studies No. 23.* Pennsylvania State University, 1967. p. 59.

143. Wood, Gene W., D.W. Simpson and R.L. Dressler. "Effects of Spray Irrigation on Forests with Chlorinated Sewage Effluent on Deer and Rabbits", *Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland.* Pennsylvania State University Press, 1973. pp. 311-323.

144. University of Missouri Extension Division, p. 31.

145. APWA, p. 102, 143.

146. Sopper, William E. and Louis T. Kardos. "Vegetation Responses to Irrigation with Treated Municipal Wastewater", Recycling Treated Municipal Wastewater and Sludge Through Forest and Cropland. Pennsylvania State University Press, 1973. p. 277.

147. Sopper and Kardos, "Vegetation Responses ...", pp. 276-279.

148. Kardos, Louis T. "The Effect of Applying Municipal Effluent on Soils, Plants, and Surface and Subsurface Water Quality", Proceedings of the Conference on Disposal of Treated Municipal Effluent on Land. University of Missouri at Columbia, March 20, 1973. pp. 33-35.

149. Sopper and Kardos, "Vegetation Responses ...", p. 275.

150. Sopper and Kardos, "Vegetation Responses ...", p. 275.

151. Smith, J.H. "Treatment of Potato Processing Waste Water on Agricultural Land", (Presented at the Pacific Northwest Pollution Control Association, 1973 Meeting, Vancouver, B.C.). p. 10.

152. Sopper, "Crop Selection ...", p. 144.

153. Sopper and Kardos, "Vegetation Responses ...", p. 279.

154. Sopper, "Crop Selection ...", p. 144.

155. Smith, p. 12.

156. University of Missouri Extension Division, p. 22.

157. Sopper, "Crop Selection ...", p. 144.

158. APWA, pp. 2, 124, 127.

159. Miller, p. 126-128.

160. Parizek, "Site Selection ...", p. 133.

161. Blakeslee, Paul A. "Monitoring Considerations for Municipal Wastewater Effluent and Sludge Application to the Land", Proceedings of the Joint Conference on Recycling Municipal Sludges and Effluents on Land. Champaign, Illinois, July 1973. pp. 183-198.

162. Chaiken, Eugene I., et al. "Muskegon Sprays Effluents on Land", Civil Engineering, ASCE (May 1973). pp. 49-53.

163. Deaner, pp. 1-64.

APPENDIX A

SURVEY QUESTIONNAIRE

WASTE WATER LAND APPLICATION

SURVEY QUESTIONNAIRE

Date ______________
Source ______________

Facility ______________ Consultants ______________
City ______________ City ______________
State ______________ State ______________
Contact ______________ Contact ______________
Telephone ______________ Telephone ______________

General:

Disposal Site Land Use ______________
Year Placed in Service ______________
Population Served ______________
Reason for Selecting Land Disposal ______________
Public Attitude ______________
Effluent User Attitude ______________

Legal:

Water Adjudication Required ______________
Legal Opposition Encountered ______________
Population Relocation Required ______________

SYSTEM DESCRIPTION

Flow and Storage:

Present Total Flow ______________ Design Total Flow ______________
Industrial Flow ______________ Signif. Indust. Constit. ______________
Retention Storage Capacity ______________ Ave. Retention Time ______________

Pretreatment:

Primary ______________ Tertiary ______________
Secondary T. F. ________ A.S. ________ Chlorination ______________
Aerated Lagoon ______________ Other ______________
Anarobic Lagoon ______________ ______________
Septic Tank ______________ Sludge Disposal Method ______________

Irrigation Water Characteristics:

BOD_5 (mg/l) ______________ S.S. (mg/l) ______________
Fecal Coliform (#/100 ml) ______________ Total N. (mg/l) ______________
Total P (mg/l) ______________ Metal Ions (mg/l) ______________
T.D.S. (mg/l) ______________ V.S.S. (mg/l) ______________
pH ______________ S.A.R. ______________

Site Description:

Irrigated Acres ____________________
Site Topography ____________________
Soil Type ____________________
Geology ____________________
Runoff Retention ____________________
Adjacent Land Use ____________________

Water Transport Distance ____________________
Soil Depth ____________________
Water Table Depth ____________________
Underdrains ____________________
Effluent Reuse ____________________
Buffer Zone Size ____________________

Irrigation Methods:

Solid Set Above Ground ____________________
Center Pivot ____________________
Ridge and Furrow ____________________

Below Ground ____________________
Portable ____________________
Overland Flow ____________________

Crops:

Ground Cover Type ____________________
Irrigation Rate ____________________
Irrigation Frequency ____________________
Annual Irrigation Rate ____________________
Rate Optimized for Crop Yield ____________________
Rate Optimized for Effluent Disposal ____

Annual Yield ____________________
Irrigation Duration ____________________
Irrigation Season ____________________
Operator ____________________

Monitoring: (tests performed, test frequency, test results)

Influent

Effluent

Ground Water

Surface Runoff

Air

Soil

Crops

Vegetation

Costs:

System Cost not including Primary and Secondary Treatment ____________
Net Annual Operating and Maintenance Costs ____________
System Cost Per Person ____________
O&M Cost Per Person ____________

Health or Nuisance Problems Encountered:

Recreational Uses of Disposal Site:

Suggestions, Comments, Recommendations:

APPENDIX B

REGION VIII SURVEY RESULTS
EXISTING SITES

TABLE B-1

LOCATION OF EXISTING SITES

Ref. No.	Site	Effluent Source	Location
Colorado			
1	Air Force Academy	AFA WWTP	Colorado Springs
2	Aurora Golf Course	Aurora WWTP	Aurora
3	Colorado Springs Sites	Colorado Springs WWTP	Colorado Springs
4	Donala Development	Development	Colorado Springs
5	East Canon	East Canon Sanit.Dist.	Canon City
6	Fitzsimmons Golf Course	Fitzsimmons Hospital	Aurora
7	Inverness Development	Indust. Development	Arapahoe County
8	Kuner-Empson Co.	Veg. Process. Plant	Brighton
9	Lake of the Pines Dev.	Left Hand Sanit. Dist.	Boulder County
10	Lakewood Golf Course	S. Lakewood Sanit.Dist.	Lakewood
11	Mechaneer West Golf Course	Fort Carson	Fort Carson
12	Pueblo West Development	Development	Pueblo
13	Roxborough Park Development	Development	Douglas County
14	Snowmass Golf Course	Snowmass at Aspen	Pitkin County
15	Taylor Park C.D.	Forest Service Cent. Disp.	Gunnison N.F.
16	Timmeron Development	Development	Durango
Montana			
17	Aerial Fire Depot	Forest Service Site	Missoula
18	Big Sky Golf Course	Development	Bozeman
19	Rexford	Rexford WWTP	Rexford
20	Rocky Boy Indian Reservation	Reservation	Havre

TABLE B-1 (continued)

Ref. No.	Site	Effluent Source	Location
North Dakota			
21	Dickenson	Dickenson WWTP	Dickenson
South Dakota			
22	Big Stone Cheese Factory	Cheese Processing Plant	Big Stone
Utah			
23	Bear River C.D.	Forest Service Cent.Disp.	by Evanston
24	Delmonte Corp.	Veg. Process. Plant	Smithfield
25	Gossner Cheese Co.	Cheese Processing Plant	Logan
26	Provo River C.D.	Forest Service Cent.Disp.	by Kamas
27	Spanish Forks Golf Course	Spanish Forks WWTP	Spanish Forks
28	Union Pacific Resort	Resort	Zion Nat. Park
Wyoming			
29	Snowy Range C.D.	Forest Service Cent.Disp.	by Centennial
30	Thayne	Thayne WWTP (& Cheese Pro)	Thayne
31	Wyoming Potato Inc.	Potato Processing	Pine Bluff

TABLE B-2

FLOW, PRETREATMENT, AND LAND USE

Ref. No.	Start Date	Present Flow (MGD)	Design Flow (MGD)	Land Use	Pretreat
Colo.					
1	1959	1.5	2.2	Golf,Landscape	TF,C,P
2	1969	1.3	1.0	Golf	EA,C,F,P
3	1960	3.0	10.0	Golf,Landscape	AS,TERT.,C,P
4	1973	AR	0.25	Golf	AS,C,P,F
5	1973	0.25	0.3	Pasture	EA,C,P
6	1951	0.5	0.8	Golf	TF,C,P
7	1974	AR	AR	Golf,Landscape	AS,C,P
8	1970	0.5	1.0	Pasture	SCREEN
9	1969	AR	0.25	Pasture	EA,C,P
10	1967	AR	AR	Golf	AS,C,F,P
11	1971	0.5	1.0	Golf	TF,C,P,F
12	1973	0.25	0.2	Golf,Landscape	AS
13	1974	AR	3.6	Golf	AS,C,P
14	1974	0.5	1.2	Golf	AS,C,P
15	1974	AR	AR	Natural Veg.	AL,C
16	1974	AR	0.4	Golf	AS,C,P
Mont.					
17	1973	0.02	0.04	Hay	AL,C
18	1974	AR	0.25	Golf	AL,P,F,C,P
19	1973	AR	0.04	Natural Veg.	AL,C,P
20	1974	AR	0.075	Forest	EA,C,P

TABLE B-2 (continued)

Ref. No.	Start Date	Present Flow (MGD)	Design Flow (MGD)	Land Use	Pretreat
N. Dak.					
21	1964	1.0	1.0	Hay	AL
S. Dak.					
22	1970	0.1	AR	Alfalfa,Hay	SCREEN
Utah					
23	1974	0.008	1 MGY	Natural Veg.	AL,C,P
24	1973	0.9	AR	Alfalfa	SCREEN
25	1972	0.07	AR	Hay	ANL,F
26	1974	0.016	0.2 MGY	Natural Veg.	AL,C,P
27	1958	3.0	3.0	Golf	TF,C
28	1964	0.016	AR	Natural Veg.	ST,C
Wyo.					
29	1974	AR	0.1 MGY	Natural Veg.	AL,C
30	1974	0.35	1.1	Not Decided	AL,C
31	1972	1.8	AR	Hay	SCREEN

CODE:
AR - As Required
AS - Activated Sludge
TF - Trickling Filter
EA - Extended Aeration
AL - 2 Cell Aerated Lagoon
ANL - Anaerobic Lagoon
ST - Septic Tank
C - Chlorination
F - Filter
P - Pond or Reservoir

TABLE B-3

WINTER DISCHARGE, STORAGE CAPACITY, AND EFFLUENT CHARACTERISTICS

Ref. No.	Present Winter Discharge	Present Storage Capacity	BOD (MG/L)	S.S. (MG/L)	Other Constituents
Colo.					
1	Stream	4 Reservoirs	6-39	7-26	
2	Stream	10 MG	6-13	20	TDS 800-1000 mg/1
3	Stream	23 MG	< 5	< 5	
4	Storage	15 MG	10-15	10-15	
5	Stream	4 MG	17		
6	Stream	2.3 MG	5-10	< 45	
7	Storage	Pond			
8	Spray	3.5 MG	High	High	Cannery Waste
9	Storage	5 Months			
10	Stream	20 MG	< 30	< 30	TDS 500-700 mg/1
11	Stream	3 MG	15	15	
12	Unknown	Unknown	< 11	< 20	
13	Storage	67 MG			
14	Storage	100 MG	< 20	< 20	
15	Storage	Lagoon	300 1b/day		Trailer Wastes
16	Storage	27 MG	< 20	< 20	
Mont.					
17	Storage	Lagoon			
18	Storage	70 MG	10	10	
19	Storage	Lagoon	25-35	25-35	
20	Storage	Lagoon			

TABLE B-3 (continued)

Ref. No.	Present Winter Discharge	Present Storage Capacity	BOD (MG/L)	S.S. (MG/L)	Other Constituents
N. Dak.					
21	Storage	Lagoon	30-35		
S. Dak.					
22	Spray	None	High	High	25% Whey By-products
Utah					
23	Storage	Lagoon	< 50		
24	None	None	High		Cannery Waste
25	Spray	1 MG	High		Whey By-products
26	Storage	Lagoon	< 35		Trailer Wastes
27	Stream	None	17-27		
28	None	None			
Wyo.					
29	Storage	Lagoon	< 40	< 50	Trailer Wastes
30	Spray	1.24 MG	712 lb/day	100 lb/day	Brine, Whey By-products
31	Spray	None	1200-1600 mg/l	200-500 mg/l	Potato Waste

TABLE B-4

REASON FOR LAND DISPOSAL AND PUBLIC/USER COMMENTS

Ref. No.	Land Disposal Reason	Public/User Comments
Colo.		
1	Low cost irrigation water	Some Odor complaints
2	Low cost irrigation water	Some algae odor & plugging problems
3	Low cost irrigation water	Good acceptance, overloaded T.F., caused odor problems
4	Low cost irrigation water	(new)
5	Maintain water rights	(new)
6	Low cost irrigation water	Good acceptance, some algae problems
7	Low cost water, 1973 state stds.	(new)
8	Low cost treatment of seasonal waste	Some odor if not kept fresh
9	Public opposition to stream discharge	Operator satisfied
10	Low flow supplement to water rights	No problems or complaints
11	Low cost irrigation water	Some odor complaints
12	Low cost irrigation water	(new)
13	Low cost irrigation water, state stds.	(new)
14	Low cost water, 1978 state stds.	(new)
15	Emergency backup system for zero discharge	(new)
16	Low cost irrigation water, 1978 state stds.	(new)
Mont.		
17	No direct discharge available for lagoon	(new)
18	No degradation stream std., low cost water	Environmentalists happy
19	Avoid discharge to reservoir	Good acceptance
20	Drinking water stream std.	(new)

TABLE B-4 (continued)

Ref. No.	Land Disposal Reason	Public/User Comments
N. Dak.		
21	Overloaded lagoons	Farmer happy
S. Dak.		
22	Former system had lagoon odors	Very good, no odor problems
Utah		
23	Seasonal, precip. > evapotranspiration	(new)
24	Low cost treatment of seasonal waste	Good acceptance
25	Low cost treatment	Good performance
26	Seasonal, precip. > evapotranspiration	(new)
27	Low cost irrigation water	Good acceptance
28	Avoid surface discharge to stream	Variable performance
Wyo.		
29	Seasonal, avoid direct discharge	(new)
30	Avoid lagoon discharge, precip. = E.T.	(new)
31	Low cost treatment of seasonal waste	Excellent performance

TABLE B-5

LAND, SOILS, AND IRRIGATION METHODS

Ref. No.	Irrigated Acres	Soil Type	Adjacent Land Use	Irrigation Method
Colo.				
1	345	Sandy Loam	Open & Housing	Solid Set
2	150	--	Housing	Solid Set
3	200	Sandy	Housing	Solid Set
4	100	Sandy Loam	Housing	Solid Set
5	20	Sandy	Housing	Flood
6	100	Clay & Sand	Farm	Solid Set
7	AR	--	Farm	Solid Set
8	110	--	Farm	Portable
9	12	--	Farm	Solid Set
10	118	--	Housing	Solid Set
11	100	Sandy Loam	Open & Housing	Solid Set
12	10	Sandy	Open	Solid Set
13	120	--	Open	Solid Set
14	120	--	Housing	Solid Set
15	2.3	Sandy Loam	Forest	Solid Set
16	120	--	Housing	Solid Set
Mont.				
17	6	Clay Loam	Farm	Surface Solid Set
18	72	Sandy Loam	Housing	Solid Set
19	9	Silty Loam	Farm	Solid Set
20	7.5	Silty Clay	Forest	Portable

TABLE B-5 (continued)

Ref. No.	Irrigated Acres	Soil Type	Adjacent Land Use	Irrigation Method
N. Dak.				
21	200	Sandy Loam	Farm	Portable Booms & Flood
S. Dak.				
22	80	Sandy Loam	Farm	Portable Booms
Utah				
23	17	Sandy	Forest	Portable
24	50	Sandy Loam	Farm	Portable Solid Set
25	40	Loam	Farm	Solid Set
26	7	Sandy Loam	Forest	Surface Solid Set
27	35	--	Farm	Solid Set
28	2	Sandy	Open	Surface Solid Set
Wyo.				
29	0.19	--	Forest	Solid Set
30	37	Gravely Loam	Farm	Solid Set
31	40	Sandy Loam	Farm	Solid Set

TABLE B-6

IRRIGATION DATA

Ref. No.	Irrigation Rate	Irrigation Duration	Irrigation Frequency	Irrigation Season
Colo.				
1	2-3"/week	6 hr/nite	1/week	May-October
2	0.25"/nite	30 min/nite	each nite	March-October
3	AR	AR	AR	March-October
4	TBD	TBD	TBD	April-October
5	Flood	3 days	1/week	May-September
6	1.5"/week	5 hr/nite	1/week	April-October
7	TBD	TBD	TBD	April-October
8		-Move When Pools Form-		All Year
9	1.25"/week		1/week	
10	1"/week	3 hrs	2/week	July-September
11	AR	AR	AR	April-October
12	AR	AR	AR	
13	TBD	TBD	TBD	April-October
14	TBD	TBD	TBD	May-September
15	2"/week	8 hrs	1/week	June-September
16	TBD	TBD	TBD	May-September
Mont.				
17	TBD	TBD	TBD	April-October
18	AR	AR	AR	May-September
19	1"/week	AR	4/week	April-October
20	0.6"/week	AR	2/week	12 Days/Year
N. Dak.				
21	AR	AR	AR	May-October
S. Dak.				
22	4.5"/month	12 hrs	1/month	All Year
Utah				
23	5"/year	AR	AR	July-October
24	AR	AR	AR	June-September
25	2"/week	1 day	1/week	All Year
26	2"/week	8 hrs	1/week	July-August
27	AR	AR	AR	May-September
28	AR	AR	AR	
Wyo.				
29	1.5"/week	7 hrs	1/week	June-September
30	1.75"/week	8 hrs	1/week	All Year
31	3.5"/week	24 hrs	1/week	October-May

AR - As required
TBD - To be determined

TABLE B-7

SITE MONITORING

Ref. No.	Site Monitoring
Colo.	
1	14 monitor stations on adjacent stream, soil tested yearly
2	None
3	TBD
4	None
5	None
6	None
7	None
8	Soil tested 4 years ago
9	None
10	None
11	None
12	None
13	None
14	None
15	4 wells being installed, soils and vegetation to be tested as required
16	None
Mont.	
17	Soil and groundwater testing planned
18	Stream water test program by Montana State University
19	None
20	Groundwater and adjacent stream to be tested
N. Dak.	
21	None
S. Dak.	
22	Yearly soil samples
Utah	
23	Groundwater to be tested
24	None
25	None
26	Groundwater to be tested
27	None
28	None
Wyo.	
29	Full 1 year soil & water test program by University of Wyoming
30	Test wells & springs to be sampled, yearly soil tests
31	Test program in conjunction with Firth, Idaho plant

APPENDIX C

REGION VIII SURVEY RESULTS

PROPOSED SITES

REGION VIII PROPOSED FACILITIES

Black Canyon of the Gunnison National Monument, Colorado.

The proposed facility would consist of aerated lagoons with chlorination and solid set spray application to 5 acres of natural vegetation on sandy soil. Natural stream outfalls are not available. System flow would be 0.063 MGD and 8 MGY. The operating season would coincide with the tourist season starting in 1975.

Boulder, Colorado.

A feasibility demonstration plot was started in the Fall 1973 in conjunction with CSU. A definitized test program has not been completed and system operation has been sporadic. Dual cost-effective studies of advance waste treatment vs. land application of Boulder effluent (presently 14 MGD) have been undertaken by two nationally known firms. Draft reports are due July, 1974.

Burlington, Colorado.

Studies are presently underway for application of aerated lagoon effluent of up to 0.9 MGD to corn and grass crops on 270 acres of silty clay loam soil. Ridge and furrow or overland flow are being considered. First stage implementation would be about 1977.

Colony Park Subdivision, Greeley, Colorado.

Consideration is being given to condominium landscape application of effluents from an aerated lagoon and polishing pond. The system would be discontinued upon extension of sewer service from Greeley.

Indianhead Development, Kelim, Colorado.

Effluents from an extended aeration system are proposed to be used on lawns and pastures (dual water system) on 1 acre lots.

Lake Park Estates, Longmont, Colorado.

Up to 0.016 MGD of effluents from an extended aeration system with a landscape-storage pond would be applied to 5 acres of lawn. A convenient outfall is not available and the soil is tight clay. Proposed start date is 1974.

Prairie Park Development, Castle Rock, Colorado.

Effluents from an extended aeration and polishing pond system would be applied to the golf course. Design flow would be 1 MGD and the starting date is 1975.

Park Headquarters, Glacier National Park, Montana.

Seasonal effluents of up to 0.25 MGD would be applied to a 57 acre horse pasture to avoid surface discharge to a stream. The treatment system would be aerated lagoons, chlorination, and a polishing pond. Land application proposals for 4 other sites have been abandoned due to environmental concerns. A study of potential impact on wildlife and vegetation has been completed. Start date would be 1975.

West Yellowstone, Montana.

Land application of 0.25 MGD is being considered as a replacement for the present percolation lagoons.

Riverside Country Club, Bozeman, Montana.

The golf course is studying the feasibility of using effluent from an adjacent trailer court.

American Crystal Sugar, Fargo, North Dakota.

Land application of sugar processing effluents is being considered for 5 company plants.

Laramie, Wyoming.

The city is considering land application of municipal effluents. Water rights appear to be a serious obstacle.